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CHOOSING THE CRITERIA FOR ESTIMATION OF THE EFFICIENCY OF SWITCHING A DIESEL ENGINE TO OPERATION ON A BIODIESEL FUEL

The paper presents the results of criterial evaluation of technical-economic and ecological indicators of a diesel engine when it is switched to operation on a biodiesel fuel. The importance of choosing the criteria is substantiated for comparative evaluation of the quality and efficiency of a diesel engine operation on the biodiesel fuel.

Key words: *biodiesel fuel, technical-economic and ecological indicators.*

Introduction

Problem statement. The problem of using alternative sources of energy from renewable raw materials is becoming increasingly important for the modern society both due to the energy crisis and the state of environment. Since the 90-s of the last century the biodiesel fuel has come to be used throughout the world as a fuel for diesel engines. In terms of ecology and economics the biodiesel fuel has a number of advantages as compared with the ordinary diesel fuel. Smaller toxicity of the exhaust gases, rather high Cetane number and good lubricating capacity should be mentioned among them. However, when a biodiesel fuel is used directly in an ordinary diesel engine, operation problems occur caused by the changed technical-economic characteristics of the engine due to high viscosity of the biodiesel fuel, low net calorific value and higher ignition point as compared with the ordinary fuel.

In order to perform comparative evaluation of the indicators of a diesel engine operation on diesel and biodiesel fuels as well as to estimate the efficiency of its operation when it is switched to a biodiesel fuel, it is necessary to choose the criteria for evaluation of technical, economic and ecological indices of a diesel engine.

Analysis of the latest research and publications. A number of research papers [2 – 6] are dedicated to the problem of estimating the operation efficiency of internal combustion engines when they are switched to alternative fuels. The analysis of these papers has made it possible to determine the character of a diesel engine operation process when it is switched to a biodiesel fuel. In the materials [2, 3] it is demonstrated that application of a pure diesel fuel causes 10 – 20% increase of the fuel consumption and of the amount of NOx discharge.

Works [4, 5] consider the influence of a palm oil-based biodiesel fuel application on a diesel engine operation efficiency, and work [6] presents the results of the influence of different biodiesel fuel types on the amount and quality of exhaust gases. The results of the experiments have shown that a biodiesel fuel application in a diesel engine causes torque and power reduction and the increased fuel consumption. It should be also noted that the efficiency of a diesel engine operation when it is switched to a biodiesel fuel depends on the content of this fuel in the fuel mix as well as on the modes of the engine operation [6]. Special attention is paid to the diesel engine performance indicators when it is switched to a biodiesel fuel. For comparative analysis of economic and ecological indices of a biodiesel engine when is switched to a biodiesel fuel it is necessary to choose evaluation criteria.

Problem statement. The goal of this work is to choose and to substantiate the criteria for evaluation of quality and efficiency of a diesel engine when it is switched to a biodiesel fuel as well as to conduct the analysis of the influence of such switching according to these criteria.

Materials and results of the research.

Physicochemical properties of a fuel are the main parameters that make it possible to evaluate its

quality. Table 1 presents the comparison of physicochemical properties of the diesel fuel D2 with the ether of a palm oil used as a biodiesel fuel [7, 8].

Table 1

Physicochemical properties of the diesel and biodiesel fuels

Fuel	Cetane number	Average heat of combustion, K_J/K_g	Kinematic viscosity, 40ºC, mm²/s	Congelation point, ºC	Cloud point of the fuel, ºC	The lowest evaporation temperature, ºC
D2	47-55	45300-46700	1,9 – 3,8	(-17) – (-8)	(-36) – (-30)	52 – 77
Ether of the palm oil	56,2	39070	4,5 (37,8 ºC)	8	6	193

The choice of criteria was based on evaluation of the influence of switching a diesel engine to a biodiesel fuel on its technical-economic and ecological indicators. The influence of the physicochemical properties of a biodiesel fuel on each of the engine indicators was taken into account.

The analysis of the research results [9] has made it possible to distinguish the main criteria that determine the efficiency of a diesel engine operation process and to find the required range of their values. To determine the resulting influence of a diesel engine operation on a biodiesel fuel, the following criteria were chosen: the engine power and efficiency, durability and reliability of its components, economic efficiency and the permissible amount of harmful substances in the exhaust gases.

On the basis of practical and theoretical works [2, 3] the criteria were divided into economic, technical and ecological ones.

Economic criteria.

The required mass of the fuel to be supplied to the engine cylinders, with the efficiency being maintained at the same level, is estimated by the formula:

$$m_e = \frac{P \cdot b_0 \cdot 33{,}33}{n \cdot z}, \text{ mg/stroke} \qquad (1)$$

where P is the engine power, kW; b_0 – effective specific fuel consumption, g/kW·h; n – the camshaft rotation speed, min^{-1}; z – the number of cylinders.

Cyclic delivery of the fuel is determined by the formula:

$$Q_H = \frac{P \cdot b_0 \cdot 1000}{30 \cdot n \cdot z \cdot \rho}, \text{ mm}^3\text{/stroke}, \qquad (2)$$

where ρ is the fuel density.

The analysis of formulas (1), (2) shows that the engine power is inversely proportional to the fuel flow rate and directly proportional to the fuel density.

From the theory of engines it is known that specific fuel consumption is calculated by the formula:

$$b_0 = \frac{3600}{\eta_i \cdot h_i}, \text{ g/kW·year}, \qquad (3)$$

where η_i – indicated efficiency of the engine; h_i – net calorific value of the fuel, KJ / g.

From this expression it follows that with the reduction of net calorific value of the fuel the specific fuel consumption increases and the obtained engine power is reduced. Research [2] has shown that the volumetric flow rate of a biodiesel fuel is approximately 10% higher than that of the ordinary fuel. Hence, for maintaining diesel engine efficiency at the constant level when it is switched to a biodiesel fuel, it is necessary to increase the specific effective flow rate and cyclic delivery of the fuel.

Biodiesel fuel application as a fuel for diesel engines has inconsiderable effect on the reliability of

engine parts. It should be noted that possible formation of coking products in the injectors and deposits in the engine cylinders reduces its operation life [10]. This problem, however, requires further study.

Technical indices.

According to formula (3), when a diesel engine is switched to the biodiesel fuel, the specific fuel consumption increases due to the reduced net calorific value of the fuel, which leads directly to the reduction of power received from the engine. This means that for obtaining the required power it is necessary to use a greater amount of fuel.

Speed characteristics (dependences of the power, torque and fuel consumption on the rotation speed) and load characteristics (dependences of the time and specific flow rates on the power and torque) of the engine when it is switched to a biodiesel fuel can become worse due to the increased fuel consumption, lower net calorific value of the fuel as compared with the ordinary diesel fuel, higher viscosity of the biodiesel fuel, the problem with combustion due to the high ignition point of the biodiesel fuel.

Ecological indicators.

Biodiesel fuel application reduces the amount of harmful substances in the exhaust gases of a diesel engine. However, some experimental data has shown that the biodiesel fuel application increases the amount of NOx emission. Biodiesel fuel has higher values of density and viscosity as compared with the ordinary diesel fuel, which could lead to its incomplete combustion. This may cause higher smokiness of the engine.

Table 2 presents the results of the analysis of a diesel engine technical-economic and ecological criteria when it is switched to a biodiesel fuel.

Table 2

Technical-economic and ecological criteria of a diesel engine efficiency when it is switched to the biodiesel fuel.

Indices	The analysis of the influence of switching a diesel engine to the biodiesel fuel
Economic	
Fuel consumption	Specific fuel consumption increases
The efficiency	Possible reduction of the efficiency
Cyclic delivery of the fuel	Possible reduction of the cyclic dlivery of the fuel
Technical	
Power	Possible reduction of the engine power
Traction-speed characteristics	Possible reduction of traction-speed characteristics
Maximal torque	Possible changes of the maximal torque
Reliability	Possible reduction of reliability of the engine components
Ecological	
The degree of toxicity and smokiness of the exhaust gases	Ecological indices of a diesel are improved with the reduction of pollutants (12% reduction of CO emission, CnHm – 35%, soot – 50%), but at the same time the amount of NOx emission increases and smokiness could become higher due to the incomplete fuel combustion

After choosing the criteria for a diesel engine efficiency evaluation when it is switched to the biodiesel fuel, a comparative analysis can be conducted on the expediency of the biodiesel fuel application as an alternative fuel for a biodiesel engine. It should be noted that these criteria make it possible to estimate the changes of all the performance characteristics of a diesel engine when it is switched to a biodiesel fuel.

Conclusion

The paper presents the results of the analysis of how the technical-economic and ecological

indices of a biodiesel engine are effected when it is switched to a biodiesel fuel. The criteria are determined for qualitative evaluation of the degree of influence of the biodiesel fuel application on a diesel engine performance and the analysis of such influence according to these criteria is conducted.

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