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METHOD OF PROVISION OF NECESSARY TECHNICAL ECONOMIC AND OPERATING CHARCTERISTICS OF DIESEL ENGINE IN CASE OF ITS TRANSITION TO BIODIESEL FUEL

Physical chemical properties of biofuel have been analyzed, its impact on engine operation has been considered. Recommendations, regarding modification and adjustment of diesel engine system while its transition to biodiesel fuel to maintain the necessary level of technical, economic and ecological indicies are given.

Key words: *diesel engine,diesel fuel ,biodiesel fuel.*

Introduction

The problem of usage of alternative sources of energy obtained from renewable raw materials becomes more and more urgent for modern society due to energy crisis and ecological problems, that is why biodiesel fuel is more and more widely used [1]. Biodiesel fuel is renewable source of energy, obtained from vegetable oil. Biodiesel fuel, from chemical point of view, is methyl ether, which is ecologically clean alternative to liquid fuel and can be used in any diesel engine without any changes [2]. However, it should be noted, that while conversion of diesel engine to biodiesel fuel certain changes in the character of engine operation mode occur. The following characteristics undergo changes: power of the engine, torque and cyclic feed.

Analysis of the latest research and publications

Nowadays many institutions deal with the problems of adoption of diesel engine for functioning on biodisel fuel.

Company “Bosch” has developed the improved fuel pumps of high pressure (FPHP) of MW and P models, which enable to pass from one kind of fuel to another [4]. These types of fuel pumps have limitation while their transition from gasoline to kerosene and bioethanol. It is also planned to develop such systems for boidiesel fuel (its addition to 5%).

Company “Bosch” has also developed the control system called “Bosch NG-Motronic” to control process while transition of diesel engines on biogas [5].

Researchers from Purdue University [6] developed the control system for reduction of specific biodiesel fuel consumption and emission of (NO_x) using the mixture of common fuel with biodiesel fuel. The system evaluates physical properties of the fuel: sensors read their properties and by the algorithms, depending on the state of mixture, automatically adjust the time and fuel injection method, as well as determine the state of exhaust gases. However, the system does not take into account and does not adjust power and torque characteristics of the engine. The modifications are made only for adjustments of the engine, but on the construction level the changes are not considered.

Physical-chemical properties of biodiesel fuel

Availability of biodiesel fuels of different origin results in their different characteristics, this is specified by various chemical composition of methyl and ethyl esters and different physical properties.

Biodiesel fuel has several advantages as compared with conventional diesel fuel, these advantages are: low toxicity (biodiesel fuel contains small quantity of toxic substances; ignition temperature is higher, than the ignition temperature of conventional fuel, that provides its safe operation , but complicates the ignition of inflammable mixture; better lubricating properties, which can increase service life of the engine).

The results of tests [3] show, that even the addition of biodiesel fuel to conventional diesel fuel in quantity less than 1% can provide up to 30% of lubricating quality increase [9].

The drawbacks of biodiesel fuel are: high temperatures of turbidity, evaporation and solidification, that complicates the usage of the fuel in cold period of the year. Data, regarding physical-chemical properties of certain esters of oils, used as biofuel and data, regarding the properties diesel fuel are presented in Table 1 [8].

Table 1

Physical-chemical properties of compound esters of oils, used as biofuel and diesel fuel

Ester of the oil	Cetane number	Average heat value (J/kg)	Kinematic viscosity (40ºC, mm/sec)	Solidification temperature (ºC)	Cloud temperature of the fuel (ºC)	Least vaporization temperature (ºC)
Cocker						
Ethyl	67.4	38158	3.08	5	-3	190
Corn						
Methyl	65	38480	4.52	-3.4	-3	111
Olive						
Methyl	61	37287	4.70	-2	-3	>110
Mustard						
Ethyl	54.9	40679	5.66	1	-15	183
Palm						
Ethyl	56.2	39070	4.50 (37.8 ºC)	8	6	193
Rape						
Methyl	56	37300	4.53	-6		169
Methyl	53.7	8850	4.96	-6		
Methyl	47.9	39870	4.76	-3	-9	166
Ethyl	67.4	40663	6.02	1	-12	170 (4)
Diesel fuel	47-55	45300-46700	1.9 – 3.8	(-17) – (-8)	(-36) – (-30)	52 – 77

Analysis of the influence of physical-chemical properties of biodiesel fuel on operation of diesel engine

Cetane number. Vegetable oils are lipids, esters of fatty acids or glycerin. Having high heat generating properties, they contain direct hydrocarbon chains, that specifies their relatively high cetane number. This provides better combustion of the fuel.

Least vaporization temperature. Biodiesel fuel has rather high vaporization temperature, this complicates its usage at low temperatures. We can assume, that usage of the fuel with high vaporization temperature can increase ignition delay and duration of fuel combustion. This can lead to incomplete combustion of fuel and correspondingly to increased fuming.

Average heat value. Energy value of biodiesel fuel is worse than conventional diesel fuel due to smaller average heat value, that leads to decrease of power and torque, however this can be compensated by the increase of cyclic fuel supply. It must be injected longer and burnt.

Kinematic viscosity. In [7] experimental relation of fuel viscosity variation on average diameter of drops while atomization is presented. Empirical formula (1) will be presented as

$$\frac{d}{d_{inp}} = \left(\frac{v}{v_{inp}}\right)^{0.5}, \tag{1}$$

where d_{inp} is known average diameter of the drop at kinematic viscosity v_{inp}; d – is average diameter of the drop if kinematic viscosity equals v.

In accordance with the formula (1) high kinematic viscosity of biodiasel fuel results in the increase of fuel drops dimensions while atomization.

If we assume, that average kinematic viscosity of diesel fuel is 2.85 mm^2/s and of palm ester – 4.5 mm^2/s, and we substitute these values in the formula, (1) then we get:

$$\frac{d}{d_{inp}} = \left(\frac{4.5}{2,.4}\right)^{0.5} = 1.3.$$

This results means that while conversion on biodiesel fuel on conditions of the experiment [7] we obtain drops 1.3 time greater than in diesel fuel, that will result in difficulty of fuel combustion and, correspondingly to incomplete combustion.

While transition on biodisel fuel duration of combustion depends on cetane number, the least vaporization temperature, average heat value and kinematic viscosity. Among these factors cetane number is the only factor that enables to reduce the duration of burning. However, since other parameters have considerable impact on the increase of burning duration, it is necessary to provide more time for injection, vaporization an combustion of the fuel.

This can be achieved by increasing the injection advance angle of the crankshaft.

Analysis of constructive and adjusting changes in the elements of diesel engine fuel system while its transition on biodisel

To provide necessary technical-economic and operation characteristics of diesel engine while its conversion to biodisel fuel such changes are possible:

- Modernization of HPFP to provide greater fuel injection pressure;
- Modernization of injectors to provide the injection of greater amount of fuel and increase of atomization area of thicker and more viscous fuel: increase of the number of holes, increase of holes diameter;
- Adjustment of the advance angle of fuel injection to provide complete burning of fuel;
- Installation of fuel heating device to decrease biodiesel fuel viscosity.

Modernization of HPFP:

Increase of fuel injection pressure provides the increase of operation range and amount of the injected fuel, correspondingly, the power must be increased.

Hiwasy suggested the general formula for calculation of operation range at the end of injection

$$S = 0.39\sqrt{\frac{2\Delta P}{\rho_f}} \cdot t, \tag{2}$$

where ΔP – is the value of pressure drop in the orifice of the injector nozzle; t – is duration of injection ; ρ_f – is fuel density.

Having considered this formula, we can draw a conclusion that high pressure of nozzle opening provides the growth of operation range while fuel injection. Since the density of diesel fuel dose not differ greatly from the density of biodiesel fuel, then the operation range will differ from this parameter.

Modernization of nozzles

The research, carried out, showed that the size of nozzle orifice influences such parameters as: operation range, quality of fuel atomization. Fuel must be disintegrated into the smallest drops, uniformly distributed in the air environment of combustion chamber. Thickness of atomization is of great importance for conversion of the engine for biofuel operation. It was established, that the quality of atomization becomes better while increase of stream speed as a result of injection pressure increase, with the increase of air pressure, compressed in combustion chamber while passage to smaller diameters of nozzles orifices of the injector. In the process of injection it is necessary to tend to formation of small fuel drops, which in their turn, are able to penetrate deeply, in all directions in compressed air environment in combustion chamber. Penetration of the drops into the compressed air environment depends on operation range of fuel stream. If operation range of fuel stream decreases fuel drops can not penetrate in the most distant parts of the combustion chamber; incomplete burning takes place, specific fuel consumption increases, power of engine drops. Thus, it can be assumed, that while conversion of diesel engine on biodiesel fuel due to smaller degree of ignition, greater viscosity it is necessary to provide rather high injection pressure, and reduction of fuel drops diameter. This will lead to the changes of the number of nozzles and diameters of nozzles sprayers orifices. Let us consider mathematical model, suggested by Dente and other researchers, which enables to determine the depth of fuel stream penetration at the end of atomization.

$$S = (v_{inj} d_0)^{0.5} \left(\frac{294.4}{T} \right)^{0.25}; \qquad (3)$$

$$d_0 = d_{inj} \frac{\rho_f}{\rho_a}; \qquad (4)$$

where v_{inj} – is the amount of injected fuel at the end of injection; d_{inj} – is the diameter of nozzle orifice; ρ_f – is fuel density; ρ_a – air density; T – temperature.

It can be seen from the formula that atomization range is directly proportional to the diameter of nozzle orifice. The conclusion can be drawn, that in order to provide the required injection range of biodiesel fuel, it is necessary to calculate the necessary diameter of nozzle orifice. Duration and injection pressure increase when the size of injector of diesel engine decreases, the amount of released NO_x also increases. Optimal construction of injector nozzle will be when it provides the complete combustion of fuel.

Adjustment of fuel injection advance angle

Variation of advance angle is not modification in the construction of diesel engine, it is only variation of its adjustment, which provides its more efficient operation. Proceeding from theoretical fundamentals of diesel engine operation control while its conversion to biodiesel fuel operation, it is necessary to set earlier advance angle of injection to provide complete combustion of biodiesel fuel while its usage as a fuel for diesel engine (provide more time for injection evaporation and ignition of the fuel).

Installation for fuel heating

One of the problems emerging in the course of engine operation on biodiesel fuel is high fuel density. It influences the performance of fuel supply system, particularly, operating of fuel pump, fuel filters and formation of fuel air mixture [10]. The research, carried out, showed that heating of biodiesel fuel improves characteristics, connected with high viscosity. Preheater allows to use biodisel fuel in cold period of the year and assures identical characteristics of viscosity, in spite of temperature difference.

Conclusions

While conversion of diesel engine for operation on biodiesel fuel it is necessary to take into account various physical-chemical properties of different fuels. This difference of properties will be manifested in variations of power and torque, in changes of fuel consumption, in changes of qualitative and quantitative characteristics of harmful substances in exhaust gases, in variations of heat mode of the engine. The advantages of biodiesel fuel are: low toxicity; greater safety (at the expense of high ignition temperature); better lubricating properties; high cetane number. The drawbacks are: high kinematic viscosity; high temperature of vaporization, turbidity and solidification; low average heat value.

To maintain or improve operation characteristics of the engine while conversion on biodiesel fuel, it is necessary to realize certain modifications, these modifications may include:

- Increase of fuel injection pressure by means of FPHP modernization;
- Increase of the number of orifices and (or) increase of nozzles orifices diameters;
- Adjustment of earlier advance angle of fuel injection.
- Mounting of the devices for fuel heating.

Further the study of each variant of engine modernization will be carried out, qualitative characteristics of operation indices at theses changes will be determined. After that objective evaluation of necessary changes in adjustment and construction of the engine will be made.

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