Utilization of Variable Consumption Biofuel in Diesel Engine

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Abstract. The depletion of oil fields and the deteriorating environmental situation leads to the need for the search of new alternative sources of energy. Actuality of the article due to the need for greater use of the alternative fuels in internal combustion engines is necessary. The advantages of vegetables origin fuels using as engine fuels are shown. Diesel engine operation on mixtures of petroleum diesel and rapeseed oil is researched. A fuel delivery system of mixture biofuel with a control system of the fuel compound is considered. The results of the system experimental researches of fuel delivery of mixture biofuel are led. Keywords — internal combustion engine, diesel engine, diesel fuel, rapeseed oil, mixture biofuel.

1. Features and advantages of biofuel using in internal combustion engines

The researches of internal combustion engines on alternative fuels become more and more actual. It is because these is a necessity of petroleum motor fuels substitution by fuels produced from alternative raw materials. Fuels produced from vegetable raw materials (biofuel) are the most attractive among the alternative fuels. These fuels are obtained from renewable raw material base – vegetable raw materials. The applying these fuels - oxygen circulation in the atmosphere can be provided and the main greenhouse gas (carbon dioxide) emission into the atmosphere can be reduced.

Bioethanol became widely used in internal combustion engines with forced ignition of operating mixture. In the context of diesel engines liquid fuels based on vegetable oils have great prospects. The rapeseed oil is considered as the most perspective source of energy [1, 2, 3]. Mixtures of petroleum diesel fuel with rapeseed oil have the greatest benefits [4, 5, 6]. Regulation of these mixtures allows improving diesel engines indexes significantly during speed and loading modes. In this way the fuel delivery system of petroleum diesel fuel and rapeseed oil mixtures should expediently be equipped with biofuel mixture compound control system.

2. Fuel delivery system of mixture biofuels in diesels

The feeding valve of high pressure line is considered to be applied as such a control system (initial pressure regulator valve). The rapeseed oil delivery into high-pressure fuel pipe is occurred through this valve [7, 8, 9]. The valve mounting scheme into the high-pressure line is shown in figure 1. The fuel system consists of two lines: diesel fuel and rapeseed oil. Every line has its own fuel-feed pump (1) and fine filter (2). Diesel fuel line operates in a conventional manner and fuel enters into fuel injection pump assembly (3) after the fine filter passing. After that fuel goes through the high-pressure line (4) to the nozzle (5). The nozzle (5) is equipped with initial pressure regulator (6) into the high-
pressure line. The high-pressure line is fed with rapeseed oil which is submitted from fuel-feed pump through the initial pressure regulator.

The regulator design is shown in figure 1, b. The system operates in the following way. Pressure control valve into fuel injection pump assembly closes after fuel cut-off, relieving the high-pressure line to avoid reinjection. Discharge value depends on uploading run of the pressure control valve (uploading volume) and operation mode of the fuel equipment. This operation mode is characterized by a rotating speed of engine crankshaft (or camshaft of the fuel injection pump assembly) and injection rate. Residual volumes form in some modes during the uploading in the high-pressure line. These volumes can be filled with an additional fuel (e.g. rapeseed oil) between feeding phases through the replenishment valve. The amount of submitted rapeseed oil through the replenishment valve depends on residual volume quantity in the high-pressure pipe. This value formed after cut-off process of the feeding.

![Image](image.png)

**Figure 1.** Feed system of high-pressure line through initial pressure regulator valve: a – system scheme; b – Initial pressure regulator; 1 – fuel-feed pump; 2 – fine filter; 3 – fuel injection pump assembly; 4 – high-pressure line; 5 – nozzle; 6 – initial pressure regulator.

3. **Fuel delivery system experiments of mixture biofuels**

The series of motor-less tests of fuel pump have been carried out. Fuel pump type – 4UTNM with FD-22 nozzle (sprayer type 145.1112110), 62 cm – light fuel pipe and 2 mm inner diameter, pressure control valves with a 3mm uploading stroke. During the experiment diesel fuel was submitted through the fuel injection pump assembly under 0.1-0.2 MPa over-pressure. This pressure was created with the fuel-feed pump. Speed characteristics of the fuel pump are shown in figure 2. They are obtained at different rail positions of the fuel injection pump assembly during the high-pressure line replenishment of diesel fuel. The experimental results show that speed characteristics of fuel feed with growing branches are formed during the line replenishment and the rotating speed increasing of fuel injection pump assembly camshaft. Fuel-feed correction and corresponding adjuster setting are necessary for diesel speed characteristic ensuring with a torque reserve. Correction level is determined with a diesel performance and it depends on a composition of mixture fuel (rapeseed oil proportion having a lower calorific ability).

Mixture fuel composition depends on replenishment value of high-pressure line through the initial pressure regulator. The peculiar experiments with fuel equipment of D-245-type diesel engine have been carried out. It has been made with the aim of replenishment value verification entering through the initial pressure regulator. Fuel amount measurement has been carried through a burette and a stopwatch. This fuel was entering the fuel-feed pump and out it one to the high-pressure line. The
dependences of fuel amount entering the high-pressure line through the replenishment valve in a cycle are shown in figure 3. These dependences are rearranged according to the cycle fuel feed at different camshaft rotation speed of the fuel injection pump assembly. According to the presented dependences it follows that the fuel amount submitted through the initial pressure regulator depends on both rail position of the fuel injection pump assembly (diesel load) and camshaft rotating speed of this one.

Figure 2. Fuel injection pump assembly speed characteristics with the high-pressure line replenishment through the initial pressure regulator at different positions of apportion controller hr (rail of fuel injection pump assembly) [mm]: 1–hr=6; 2–5; 3–4; 4–3; 5–2; 6–1; 7–0.

Figure 3. The replenishment volume change of the high-pressure line (qp) depending on the cycle fuel feed (qc) and camshaft rotating speed of the fuel injection pump assembly nTN [rev-1]: 1–nTN=1300; 2–1200; 3–1000; 4–800; 5–600; 6–400.
Mixture fuel with a different concentration of rapeseed oil will be formed in the fuel pipe depending on an engine operation mode, during the rapeseed oil feed through the initial pressure regulator. The obtained dependences allow to measure rapeseed oil concentrations change at the mixture in the area of diesel operating modes. Such characteristic for diesel engine D-245-type is shown in figure 4. Assessment of obtained mixture fuel concentrations (that is submitted into the engine cylinder in different operation modes) can be realized with the characteristic. According to the characteristic, maximum concentration of rapeseed oil in the mixture is obtained in modes with a low loads and a high rotating speeds of diesel crankshaft. Rapeseed oil concentration in a high-loads zone reduces till 25% at nominal conditions and to the zero in a maximum torque zone. Rapeseed oil concentration does not exceed 15% on idle. The replenishment into the high-pressure line is absent in the launching mode and clean diesel fuel comes to the nozzle.

![Figure 4](image_url)

**Figure 4.** Rapeseed oil concentration change in mixture fuel for D-245-type diesel engine with the replenishment system of the high-pressure line through the initial pressure regulator valve.

4. Conclusion
The carried out experiments of mixture fuel preparation system in the high-pressure line through the replenishment valve showed an opportunity of its application at D-242 and D-245-type diesel engines. The system allows providing the rapeseed oil concentration change in mixture fuel from 0 to 100% depending on the operation mode. Oil concentrations in fuel below are provided during the operation mode due to the proposed system (shown in figure 4):

- rapeseed oil concentration in mixture changes from 0 to 25% in full-load modes. What is more, high values of the concentration are obtained in maximum rotating speeds of the engine crankshaft. Such value concentrations will not impair power and economical diesel data in maximum loads;
- rapeseed oil concentration in mixture on idle modes changes from 15% at low rotating speeds of engine crankshaft to 100% at maximum rotating speed. Such concentrations will not affect to diesel operation in crankshaft low rotating speed modes. But the rapeseed oil concentration increase till 100% in the mixture fuel should not significantly impair diesel operation. It is because a quality of mixture formation in these modes is joined with an intensive air charge movement and high values of air-fuel ratio;
- fuel with 15% rapeseed oil concentration is in the system after minimum rotating speed modes of the engine crankshaft on idle (before stopping). And engine stop in this mode will save the same oil concentration in a start mode (i.e. 15%). It will ensure good starting properties of the engine;
- an abrupt rapeseed oil concentration change was not observed in a mixture during transition from one operation mode to another. So a smooth diesel power change should be provided during its operation.

Thereby the fuel based on rapeseed oil can be used in diesels without special changes. This fuel is one of the most perspective through alternative fuels for diesel engines. The applying of high-pressure line replenishment system allows obtaining mixture fuel directly in the diesel engine fuel system through a special replenishment valve. The obtaining rapeseed oil concentrations in a mixture fuel provide saving of power and economical diesel indexes by using this system and its starting qualities saving after engine stop.

References

[1] Hemmerlein N, Korte V, Richter H, Schröder G 1991 SAE Technical Paper Series Performance, Exhaust Emissions and Durability of Modern Diesel Engines Running on Rapeseed Oil, 910848 pp 1-16, DOI: https://doi.org/10.4271/910848.
[2] Hashimoto M, Dan T, Asano I, Arakawa T 2002 SAE Technical Paper Series Combustion of the Rape-Seed Oil in a Diesel Engine, 2002-01-0867 pp 1-12, DOI: https://doi.org/10.4271/2002-01-0867.
[3] Spessert B M, Schleicher A 2007 MTZ Worldwide Influence of biofuels on exhaust gas and noise emissions of small industrial diesel engines, 68(3) pp 17-20, DOI: https://doi.org/10.1007/BF03226815.
[4] Markov V A, Devyanin S N, Semenov V G, Shahov A V, Bagrov V V 2011 Using Vegetable Oils and Vegetable Oils Based Fuels in Diesel Engines (Moscow: LLC Scientific Research Centre Engineer, LLC Oniko-M Publ.) p 527, URL: http://www.rfbr.ru/rffi/ru/books/o_1783214.
[5] Aleksandrov A A, Arkharov I A, Bagrov V V, Gayvoronskiy A I, Grekhov L V, Devyanin S N, Ivaschenko N A, Markov V A 2012 Alternative Fuels for Internal Combustion Engines (Moscow: LLC Scientific Research Centre Engineer, LLC Oniko-M Publ.) p 790.
[6] Markov V A, Bashirov R M, Gabitov I I 2002 Toxicity of Diesel Exhaust Gases (Moscow: Publ. of Bauman Moscow State University) p 376.
[7] Grekhov L V, Ivaschenko N A, Markov V A 2005 Fuel Supply Systems and Diesel Engine Control Systems (Moscow: Legion-Avtodata Publ.) p 344.
[8] Gayvoronskiy A I, Markov V A, Ilatovskiy Yu V 2007 Use of Natural Gas and other Alternative Fuels in Diesel Engines (Moscow: LLC IRTS Gazprom Publ.) p 478.
[9] Patrakhal’tsev N N 2008 Increasing of Economic and Environmental Qualities of Internal Combustion Engines by Using Alternative Fuels, (Moscow: Publ. of Russian University of Peoples’ Friendship) p 248.