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MULTIFUEL POWER SUPPLY SYSTEM OF THE DIESEL ENGINE

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Abstract: The design of the fuel system of the tractor diesel with the multistage heating, allowing to apply pure rapeseed oil as fuel in the diesel engine is described in the article.

Key words: *fuel, rapeseed oil, kinematic viscosity, fuel system, multistage heating*.

INTRODUCTION

Despite the development of new deposits of traditional energy sources, the question of their alternatives is extremely sharp. The reason for it is the fact that natural resources are limited, the prices for traditional energy sources constantly increase while the ecological situation on the planet gets worse.

The researches in the field of alternative and renewable fuels have been the prerogative of the energy and resource saving programs of many countries for a long time [6]. Many scientists of world-wide reputation achieved good results in the sphere of alternative energy sources. Data released in the sphere of atomic energy, solar energy, the usage of wind power generators and tidal energy of seas and oceans, as well as the application of biofuels revealed the positive points of alternative power-engineering, defined tasks and the ways of their solutions. Inspite of high variability of alternative power-engineering, the majority of scientific works with positive results won’t get wide manufacturing application in the nearest future for many reasons. Therefore, many European scientists and engineers think that “atom”, “hydrogen” and recuperative system will be applied in manufacturing only in 40-50 years. This time will take a

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transitional period, when biofuel will be used as a fuel for already existing combustion engine models [8]. By now biofuel gained trust and confidence of many countries. It is used in its pure state (alcohols replacing gasoline; biodiesel replacing traditional mineral diesel fuel; biogas in gas generator units) as mixtures with mineral fuels (*E5, E15, E80, E85, B10, B20*, etc.) and as a fuel additives [7,8].

In the context of agricultural enterprises the most suitable alternative for diesel fuel nowadays is bleached RO, meeting the requirements of the German standard *V 51605*. The use of pure RO as a fuel for diesel engines results in the following negative effects: loss of power, increased fuel consumption, shortened life of the fuel equipment, impair starting in cold weather, increased incrustration and lacquer formation, etc. [1,2].

The presence of negative moments in the operation of diesel engines due to *RO*, is primarily connected with the increased values of the kinematic viscosity compared to diesel fuel (*DF*). In terms of agricultural enterprises heating is the most effective way to reduce the viscosity of the pure *RO* and its mixtures with diesel fuel with a high content of *RO*.

Based on the temperature characteristics and the seasonal field work, we investigated the dependence of the kinematic viscosity of the pure *RO* and its mixtures with diesel fuel on the temperature and the content of the *RO* in the mixture with diesel fuel.

As the RO we used a sample obtained by hot pressing followed by filtration settling of these breeds of rape: *Northerner, Salsa, Ahat, Luned, Rohan, Krauser, Solar KL, Mobil KL, Lighthouse, Zorn, Proxima, Capital, Leader, Winner, Sfint* and *Heros*. The *DF* applied in the research met the requirements of *GOST R 52368 - 2005* "The National Standard of the Russian Federation”. Diesel fuel Euro. Specifications were in line with quality D, class 2.

In the process of research we determined the kinematic viscosity of pure *RO*, as well as its mixtures with *DF*, where *DF* content was gradually increased to 100% in 10% increments. The temperature range of viscosity determination was from 20^0 to 90^0 C. The determination of kinematic viscosity was carried out according to *GOST 33-2000* "Oil products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity". The mixture heating was conducted in a water-bath, the instruments for measuring kinematic viscosity were capillary viscometers type *IWF*-1m. The experimental methods were treated with the methods of interpolation and extrapolation.

RESULTS AND DISCUSSION

The determination of dependences of kinematic viscosity on temperature and composition of fuel mix (Figs. 1 and 2) was the result of the researches, first of all.

The more *RO* the mixture contains, the lower the content of harmful substances in the exhaust gases and the fuel price and the higher energy independence of the enterprise (on condition of intrafarm *RO* production), however the kinematic viscosity of the mixture is higher. At a temperature of 0°C the *RO* viscosity is by 36,67 … 22,003 times higher than of the *DF*. Gradual temperature increase of the fuel mixtures to 40°C gives sharp decrease in viscosity. For example, at pure *RO* the kinematic viscosity of the testing sample while heating to 40°C decreases by 4,5 times in comparison with value at

0°C and attains 24,503 cSt. Further temperature increase entailed to slower decrease in viscosity. And at a temperature of 90°C the viscosity of pure *RO* attains the value of about 7,384 cSt that allows to minimize the above-mentioned negative moments at operation of diesel engines of a domestic production on this fuel.

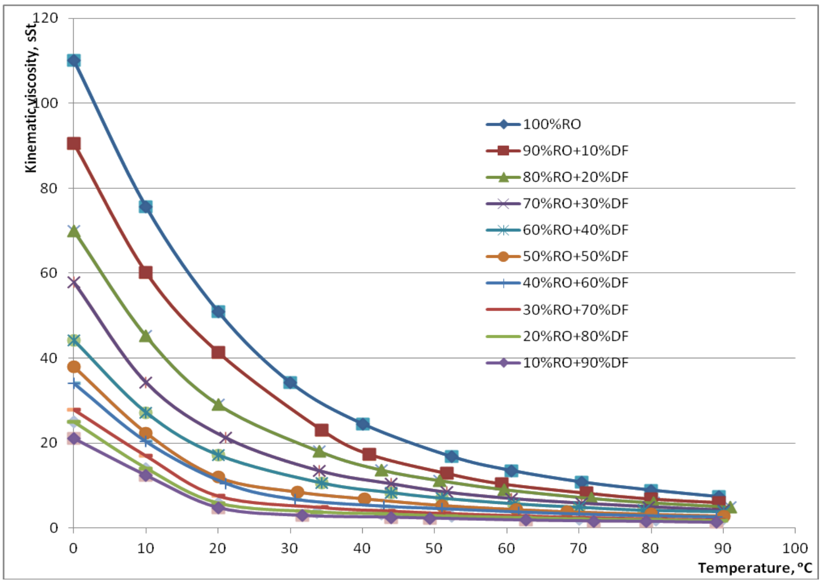

Figure 1. The dependence of the fuel mixture kinematic viscosity on temperature

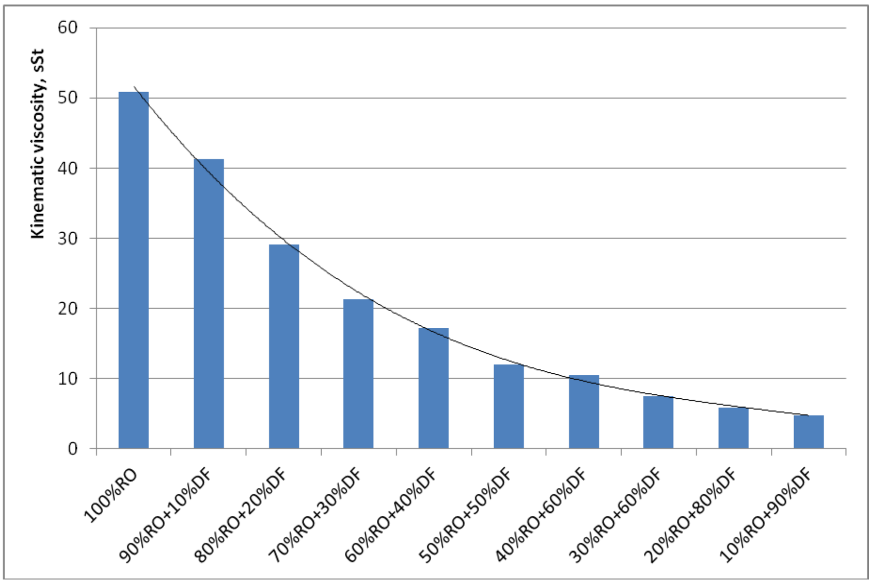

Figure 2. The dependence of the fuel mixture kinematic viscosity on its content at a temperature of 20°C

For temperature range from 0 to 40°C for all the fuel mixtures sharp decrease in viscosity is typical. The raised content of *DF* in them (from 40% and more) also gives decrease in fuel mix viscosity.

In general the analysis of the results of researches with testing samples confirmed the possibility of use as fuel for diesel engines fuel mixtures containing less than 30% of *RO* at an ambient temperature 20°C. However, the use of fuel mixtures with the low content of *RO* is ineffective from the point of view of ecology and economy, and the use of fuel mixtures with the high content of *RO* without heating is impossible. The heating of *RO* up to the temperature of 700 … 90°C provides decrease in kinematic viscosity, increase in the fineness of injection, reduce of the flame length, i.e. promotes the improvement of the carburetion and combustion processes [3].

We offered a design (Fig. 3) of a dual-fuel system of the tractor diesel with *RO* multistage heating, which provides the use of vegetable-based oil. It contains a mineral fuel tank 1, a vegetable-based fuel tank 2, where are a heat exchanger 6 and a temperature sensor 21 of the vegetable-based fuel set, mineral fuel intake line 3, vegetable-based fuel intake line 7, hydraulic directional valve 11 located in front of the fuel fine filter 12, ultrasonic filter 13 located in front of the injection pump 14, electric heaters 16 located in front of the nozzles 15, a fuel drain line 17 from the nozzles 15 and a fuel drain line 18 from the injection pump 14, an electronic control unit (*ECU*) 19, a position sensor 20 of the fuel pump rail, located in the fuel pump regulator body. Line 3 of the intake mineral fuels contains first -stage fuel filter 4 and an electric booster pump 5 with a pressure relief valve. Line 7 of the vegetable-based fuel intake, in its turn, contains first-stage fuel filter 8, fuel pump 9 of a standard power supply system and the *PTC* thermistor heater 10. [9]

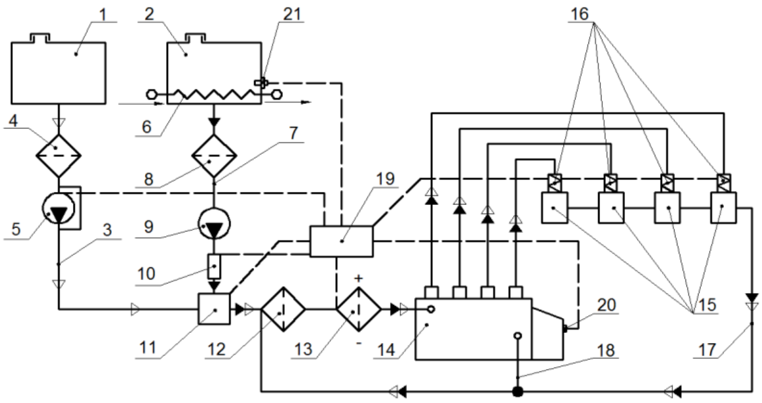

Figure 3. The diagram of a multifuel power supply system of the diesel engine

The first heating stage includes heat exchanger 6, connected to the engine cooling system and heating the vegetable-based oil in tank 2 to the temperature of 20 ... 30°C, that ensures its pumpability even at low ambient temperatures.

The second step of heating is one of the most problem parts of the fuel system which includes booster pump, fine filter and high pressure fuel pump (a fuel site of low pressure). The reason for it is that the standard fine filter of *DF* possesses some resistance of pumpability and isn't intended for filtering more viscous, in comparison with *DF*, vegetable and mineral mixtures. Therefore standard booster pumps combined with standard fuel fine filters don't provide necessary productivity. The heater design 10 (Fig. 3) offered by us allows to solve this problem with minimum changes in the standard fuel system. Application of this heater will allow to increase the efficiency of a heat-transfer process, and, therefore, to apply *RO* and its mixtures with *DF* as fuel to diesel engines. A site of low pressure, in front of the fuel fine filter, is a possible installation site.

The heater consists of the case 1 (Fig. 4) in the form of the union made of dielectric material. It is possible to use textolite as dielectric material which has also good mechanical properties. Posistors 4 are fixed in the case 1 perpendicular to its axis on the forming spiral with an equal step. In their form posistors 4 (Fig. 5) represent a circle segment, equal, for example to 2/3 of a circle. Careful mixing of liquid while heating and consequently more effective heat-transfer process are provided thanks to a special form of posistors 4 and their arrangement in the case of heater 1. Posistors 4 are powered from a vehicle's lighter socket by means of the current-carrying plates 2, located in the case 1. To simplify the assembly process the posistor 4 and the current-carrying plates 2 can represent a one-piece unit. Besides, the current-carrying plates 2 serve as fixing elements for posistors 4. The design allows to unite analogous poles of the current-carrying plates 2. The posistors 4 are powered in-parallel; it also increases the reliability of the heater. The case 1 is encapsulated by the insulating material 3, epoxy resin for example. Besides, the use of epoxy allows to increase the structural rigidity.

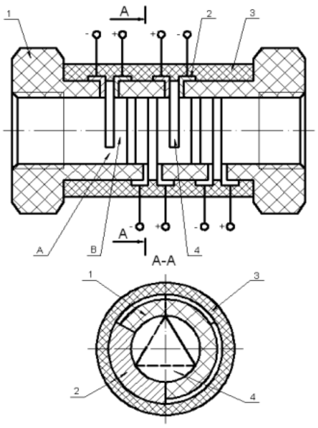

Figure 4. The arrangement drawing of a fuel heater

The form of posistors as a segment of a circle provides the greatest surface contact area with fuel, and their arrangement in the case stands for the effective mixing of the fuel in the heater.

The fuel heater works in the following way.

Before the start-up of the engine the heater is connected to the current source, for example to the vehicle battery. When the current flows through the posistors, they heat up and give their warmth to the fuel. When the fuel is heated to the set temperature, which is the characteristics of the posistors, they "are locked", in other words the resistance of the posistors increases at least in one thousand times that reduces current flowing through the posistors and the serially connected lamp (it isn't shown in the figure). After the lamp is switched of, the engine starts.

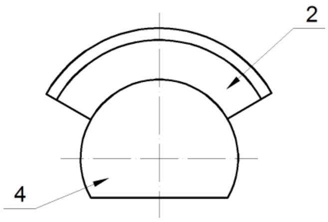

Figure 5. The drawing of the form of a posistor

The fuel, passing channel *A*, gets into a cavity *B*, hitting a posistor wall, swirls and washes the walls of the posistors, forming a cavity, then through the next channel it gets into the next cavity. Thus, consistently passing from one cavity to another, the mode of effective passive mixing is reported to the fuel that in its turn allows to increase the heat-transfer process efficiency.

The third stage of heating is realized as electric heaters 16 mounted directly in front of the nozzles 15. The vegetable-based oil at this stage is heated to a temperature of 80 ... 90°C. Electric heaters 16 contain posistors, which stand for control units, so they are self-regulated. The heating of the vegetable-based oil to a temperature of 80 ... 90°C during injection ensures less flame length and a finer spray compared with lower preheating temperatures.

The dual-fuel system of a tractor diesel with multistage heating operates in the following way:

The start and warming up of the engine is carried out on diesel fuel. At the same time it is supplied by the electric boost pump 5 from the tank through the first- stage fuel filter 4, hydraulic directional valve 11, the fine filter and ultrasonic filter 13 in the high pressure pump 14. Then the diesel fuel through the electric heaters 16 is supplied to the nozzles 15. When the engine is warming up and during the operation with diesel fuel ultrasonic filter 13 and electrical heaters 16 are switched off. The excess of diesel fuel from the nozzles 15 and the fuel pump 14 through the drain lines 17 and 18 are supplied to the fine filter 12.

When heating and during the engine operation the coolant of its system circulates through the heat exchanger 6. Once the temperature of the vegetable-based oil reaches the level of 20 ... 30°C in the tank 2 of the electric control unit 19, perceiving this option by the temperature sensor 21, switches the hydraulic directional valve11 in the position of supplying vegetable-based oil and also starts the work of heaters 10 and 16 as well as ultrasonic filter 13. The main function of the ultrasonic filter 13 is further reduction of the kinematic viscosity of the vegetable-based oil.

After switching the hydraulic directional valve 11 in the position of supplying vegetable-based oil, the oil supply stops because the ECU 19 turns the electric boost pump 5 off (the ECU 19 gives signal for the spool of the hydraulic directional valve to stop the diesel fuel supply into the system), the fuel boost pump 9 of the standard power system, delivers warmed to 20 ... 30° C vegetable-based oil from tank 2 through a first-stage fuel filter 8 into the posistor heater 10 where it is heated to 60 ... 70° C. Then the oil is sent by the hydraulic directional valve 11 through the fine filter 12 in an ultrasonic fuel filter 13, where the vegetable-based oil is subjected to cavitation treatment, whereby its viscosity is further reduced, and it is supplied into the high pressure pump 14 and then to the electric heaters 16, where it is heated up to 80 ... 90° C and the injection nozzles 15 spray it into the combustion chamber. The excess of vegetable-based oil from the nozzles 15 and the high pressure pump 14 through the lines 17 and 18 are sent to the fine filter 12.

Thanks to the use of *PTC* thermistor in the heaters 10 and 16, the latter automatically maintain the temperature of vegetable-based oil in the fuel system. In the *PTC* heater 10, they have two functions: they are heating elements and at the same time they maintain the oil temperature in the range of 60 ... 70°C. The heating elements in the electric heaters 16 are spirals, while posistors serve as elements supporting the temperature in the range of 80 ... 90°C.

At steady state conditions of the minimum stable speed and regimes of part-load engine (to 35%), the latter runs on diesel fuel [4]. When working on the above-mentioned modes the rail position sensor 20 of the fuel pump sends a signal to the *ECU* 19, which puts the system on diesel fuel. The *ECU* 19, used in the dual-fuel system, allows a person to switch from one fuel to another one manually[10].

Before stopping the engine, the fuel system is converted to pure diesel fuel and the engine should run on it for about 5 minutes (depending on operating mode).

The usage of the offered dual-fuel system of the tractor diesel engine will allow to apply vegetable-based oil as a fuel in cold season and improve the overall efficiency of the engine on this type of fuel.

CONCLUSIONS

1. The dependences of kinematic viscosity on temperature and content of fuel mix are defined.
2. The existing recommendations about application of the fuel mixtures on the basis of vegetable-based oils are added.
3. The devices allowing to apply biofuel on the basis of RO as fuel to diesel engines are developed.

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VIŠEGORIVNI POGONSKI SISTEM DIZEL MOTORA

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Sažetak: U radu je opisana konstrukcija sistema za napajanje gorivom traktorskog dizel motora sa višestepenim grejanjem, koji omogućuje primenu čistog uja uljane repice kao goriva za dizel motor.

***Ključne reči**: gorivo, ulje uljane repice, kinematička viskoznost, system za napajanje gorivom, višestepeno grejanje*

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