

## Fuel system for diesel engine with multi-stage heated

**Yu N Ryzhov<sup>1</sup>, Yu A Kuznetsov<sup>1</sup>, A V Kolomeichenko<sup>1</sup>, I S Kuznetsov<sup>1</sup>, R Yu Solovyev<sup>2</sup>, S N Sharifullin<sup>3</sup>**

<sup>1</sup>Federal State Budgetary Educational Establishment of Higher Education „Orel State Agrarian University named after N.V. Parakhin”, Russia

<sup>2</sup>Federal State Budgetary Scientific Institution “Federal Scientific Agroengineering Center of All-Russian Institute of Mechanization”, Russia

<sup>3</sup>Kazan Federal University, 18 Kremlyovskaya street, Kazan, 420008, Russian Federation

[kentury@rambler.ru](mailto:kentury@rambler.ru)

**Abstract.** The article describes a fuel system of a diesel engine with a construction tractor multistage heating, allowing the use of pure rapeseed oil as a diesel engine fuel. The paper identified the kinematic viscosity depending on the temperature and composition of the mixed fuel, supplemented by the existing recommendations on the use of mixed fuels based on vegetable oils and developed the device allowing use as fuel for diesel engines of biofuels based on vegetable oils.

### 1. 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 [1,6,7]. 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. In spite 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 transitional period, when biofuel will be used as a fuel for already existing combustion engine models. 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 [2,7].

In the context of agricultural enterprises the most suitable alternative for diesel fuel nowadays is bleached vegetable oil (VO), meeting the requirements of the German standard V 51605. The use of pure VO 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 incrustation and lacquer formation, etc. [1,3,8].

The presence of negative moments in the operation of diesel engines due to VO, 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 VO and its mixtures with diesel fuel with a high content of VO.

## **2. Materials and methods.**

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 by 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 VO, 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 to 90°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

## **3. The results of the research.**

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

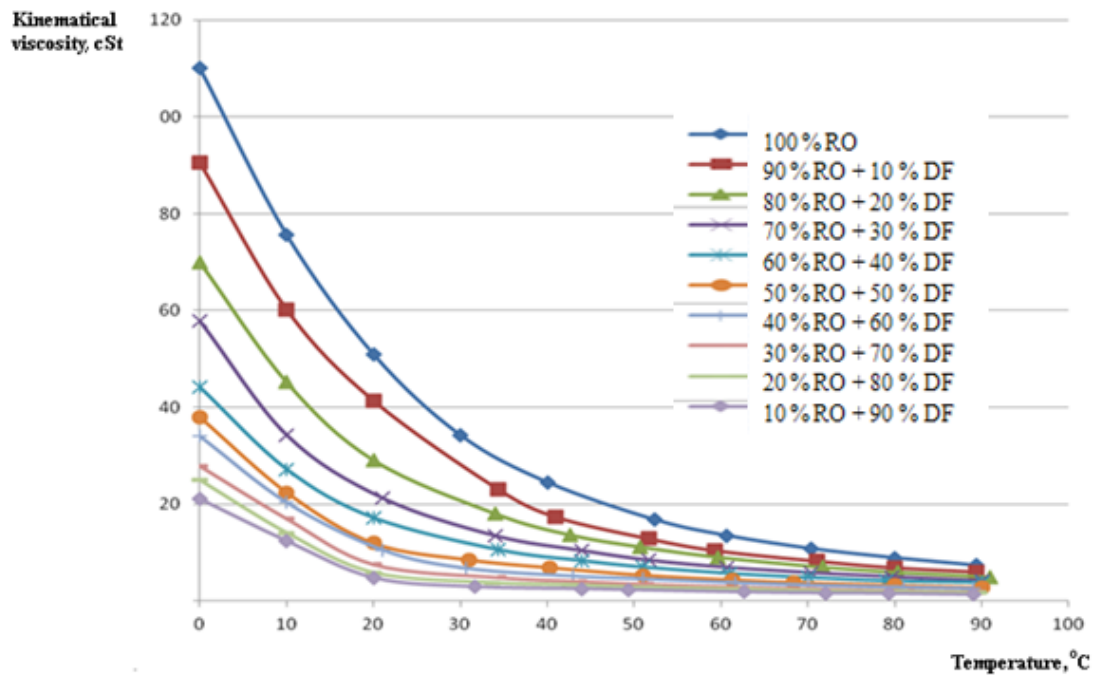
The more VO the mixture contains, the lower the content of harmful substances in the exhaust gases and the fuel price and the higher energy independence of the enterprise (on condition of intrafarm VO production), however the kinematic viscosity of the mixture is higher. At a temperature of 0°C the VO 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.

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.

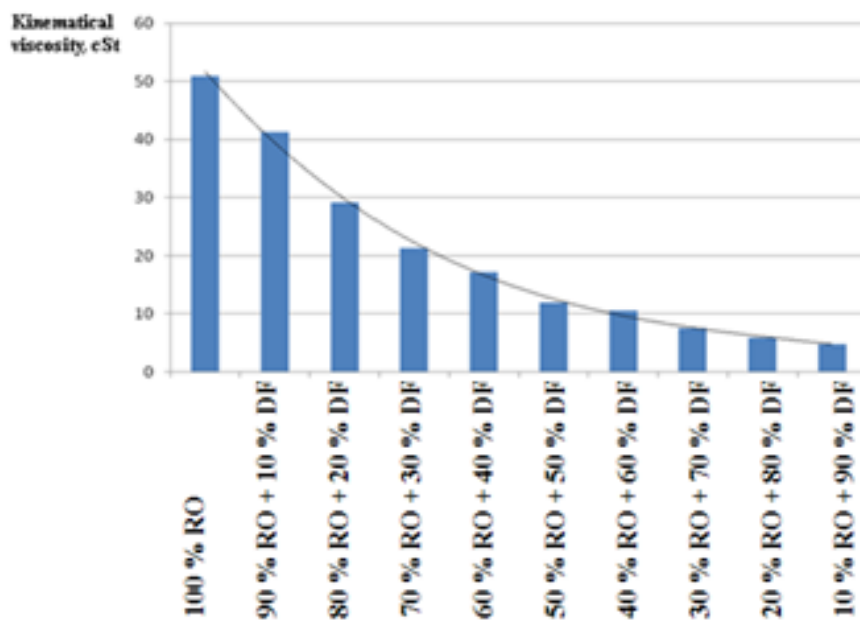
In general the analysis of the results of researches with testing samples confirmed the possibility of use as fuel for diesel engines fuel mixtures containing less than 30% of VO at an ambient temperature 20°C. However, the use of fuel mixtures with the low content of VO is ineffective from the point of view of ecology and economy, and the use of fuel mixtures with the high content of VO without heating is impossible. The heating of VO up to the temperature of 70 ... 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 [5].

We offered a design (Fig. 3) of a dual-fuel system of the tractor diesel with VO 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,

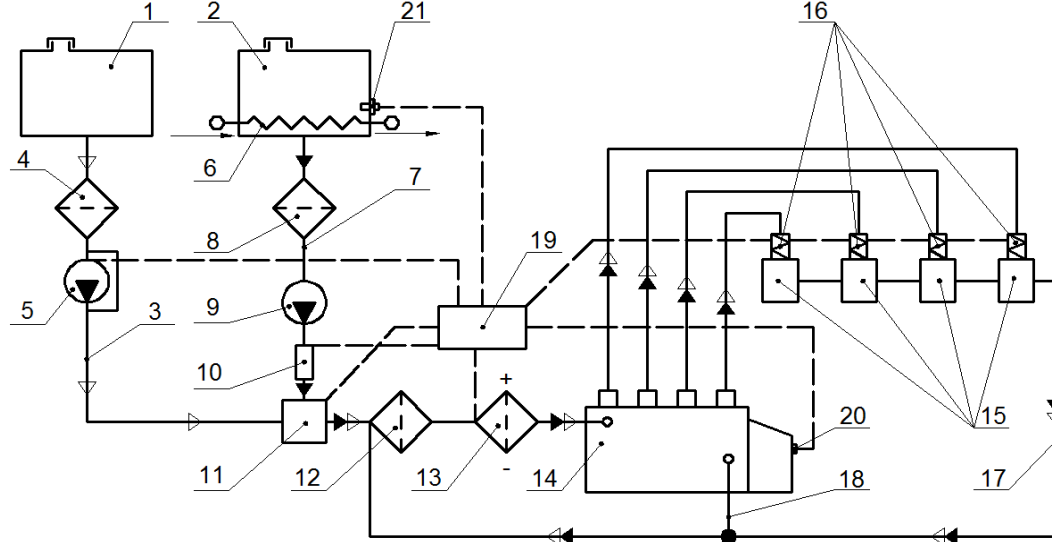
mineral fuel intake line 3, vegetable-based fuel intake line 7, electro hydro dispenser 11 located in front of the fuel fine filter 12, ultrasonic filter 13 located in front of the injection pump 14, electric heaters 16 located in front of the nozzles 15, a fuel drain line 17 from the nozzles 15 and 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 posistor heater 10 [4].



**Figure 1.** Dependence of the kinematic viscosity of the fuel mixture temperature



**Figure 2.** The dependence of kinematic viscosity on the component composition at 20 °C



**Figure 3.** The diagram of the dual-fuel system of the tractor diesel with multistage heating

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 heating stage is represented by posistor heater 10, which is self-regulated and serves to heat the vegetable-based oil to a temperature of 60 ... 70°C, which ensures its good pumpability through the fine filter 12 and ultrasonic filter 13.

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, electro hydro dispenser 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 electro hydro dispenser 11 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 electro hydro dispenser 11 in the position of supplying vegetable-based oil, the oil supply stops because the ECU 19 turns the electric boost pump 5 off (spool electro hydro dispenser at the signal, the ECU 19 blocks the access of diesel fuel in 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 electro hydro dispenser 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.

Through the use of PTC resistors in 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.

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.

#### 4. Conclusion.

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 VO as fuel to diesel engines are developed.

#### References.

- [1] Devyanin S N, Markov V A, Semenov V G 2007 *Vegetable-based oils and fuels for diesel engines* Moscow State Agrotechnical University Pp 400
- [2] Government of the Russian Federation 2012 *Comprehensive Biotechnology Development Program of the Russian Federation for the period until 2020* dd 24 No 1853-p
- [3] Kurochkin A A, Josan A A, Ryzhov Y N, Golovin S I 2013 Heated rapeseed oil as a way to improve the efficiency of its use as a fuel *Herald Eagle GAC* No 1 (40) pp 209-12
- [4] Kuznetsov Yu A, Ryzhov Yu N, Kurochkin A A, Mikhaylova Yu L, Mikhaylov M R 2014 Dual-fuel system of the diesel with multi-stage heating, running on compounded (plant and mineral) fuels in a climate of russian federation *Tractors and power machines* No 2 pp 36-40
- [5] Ryzhov Y N, Josan A A, Kurochkin A A 2012 The peculiarities of the injection and combustion of rapeseed oil and diesel fuel in modern engines *Tractors and farm machinery* No 6 pp 19-20
- [6] Ryzhov Y N, Inshakov A P, Kurochkin A A 2014 Dual-fuel system of the tractor diesel with multistage heating *Tractors and farm machinery* No 6 pp 11-13
- [7] Savelyev G S 2010 *Technologies and means of automotive equipment adaptation to the work on alternative fuels* Dis.Doc. Engineering Sciences: 05.20.01; Moscow State Research Institution All-Russian Scientific Research Institute of Farm Mechanization pp 304
- [8] Ukhanov A P, Ukhanov D A, Rachkin V A, Ivanov V A 2015 *Three-fuel system tractor diesel* Pat 2403431 RF, IPC C 1 F02M43 / 00,. No 2009116953 / 06