PROVISION OF REQUIRED VISCOSITY INDEX FOR BIPROPELLANT FUEL

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Abstract: *The article studied the possibility of providing the required viscosity for bipropellant fuel in various proportions of diesel and biodiesel fuels by the initial heating of biodiesel. We have determined the temperature of biodiesel at which the viscosity of bipropellant fuel remains at the level of viscosity of diesel fuel*

Keywords: *Viscosity, Biodiesel, diesel, fuel mixture.*

1. Introduction

For modern society the problems associated with environmental pollution and limited amount of fossil energy sources become more and more popular. One of the major pollutants of the environment and the consumer of liquid petroleum fuel oils is motor transport, in particular such element, as the internal combustion engine. So very important is the use of alternative types of fuel [1].

The main task of modern times is searching for alternative renewable types of fuel that could partially, and in future completely replace traditional fuel of fossil origin. For diesel internal combustion engine promising is the use of biodiesel and its mixtures with diesel fuel. Biodiesel from a chemical point of view – is a methyl ester of vegetable oils, which is an ecological alternative of liquid petroleum fuel. However, it differs from the diesel fuel in many parameters, one of the most important and which can be influenced - viscosity.

2. Main part

When converting a diesel engine to ecological biodiesel fuel or to bipropellant fuel it is necessary to study fuel properties. One of the main characteristics that differs significantly is the fuel viscosity. The viscosity of diesel fuel (DF) is by 20-60% less than the viscosity of biodiesel fuel. Such a large difference in the values will have a number of negative effects: reducing of elements resource of fuel supply system due to the pressure increase on them, deterioration of process of fuel spraying and burning. The problem of high viscosity can be solved by using mixed fuels with a low content of BF or using fuel heater that will provide the required temperature, and viscosity respectively, depending on the fuel used. Figure 1 shows the dependence of bipropellant fuel viscosity from its percentage content of BF, the data was obtained experimentally [2]. As can be seen from the diagram the dependence is similar to exponential dependence. No clear evident extreme points there.

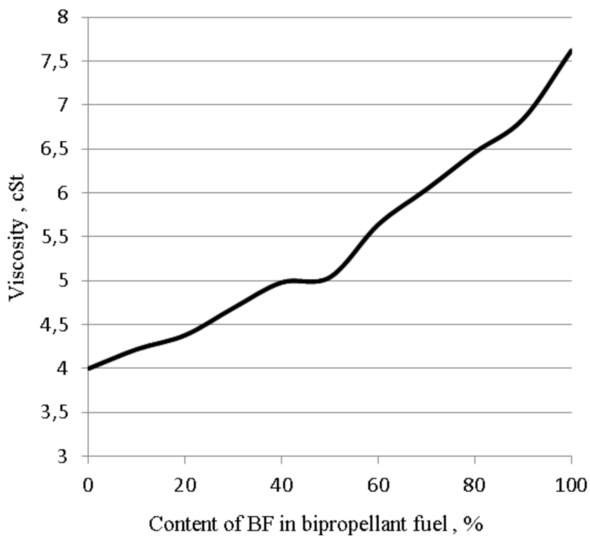

Figure 1: *Viscosity of bipropellant fuel depending on percentage content of BF in it*

In the work [2] it was conducted researches as a result of which it was established that change of fuel viscosity depends on the temperature for a number of fuels among which are BF and DF. Received dependencies – exponential equation:

for DF $y = 53{,}1\cdot x^{-0{,}81}$;

for BF $y = 106{,}1\cdot x^{-0{,}85}$.

Their graphic presentation is shown in figure 2.

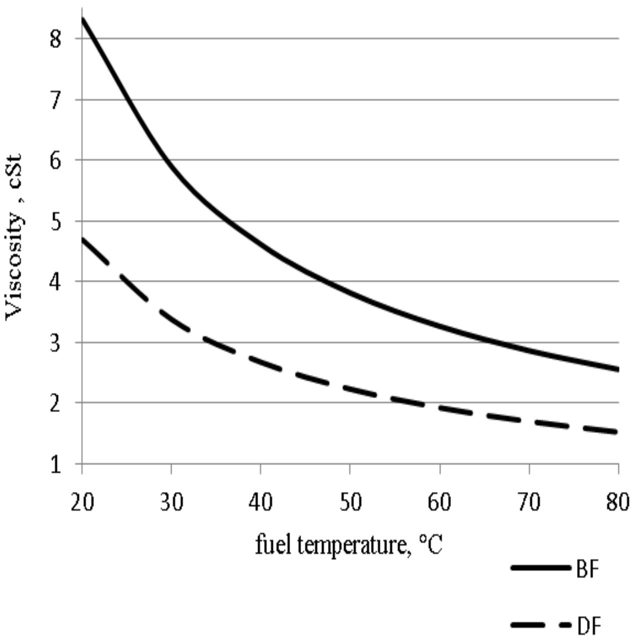

Figure 2: *Viscosity of BF and DF depending on its temperature*

To ensure acceptable viscosity of bipropellant fuel in a wide range of BF content you need to change its temperature. Accordingly, for each value of BF content in the mixture it is necessary to provide certain temperature of bipropellant fuel. Taking into consideration dynamic changes in percentage composition of bipropellant fuel and lag effect of fuel preheat system to maintain the same fuel viscosity is difficult. It is therefore advisable to heat only BF to a certain temperature, which will provide the increase of BF content in bipropellant fuel and increase of its temperature, accordingly the viscosity will be the same level. It is therefore necessary to conduct a study to determine BF temperature that will ensure the required viscosity index at different concentrations of BF in bipropellant fuel, if possible

Let's determine the effect of BF temperature on the total temperature of bipropellant fuel.

Taking into account that the chemical composition of BF and DF are very similar, we consider the values of their heat capacity so similar that it will affect the results of calculations and will be in the range of acceptable error. Let's calculate the temperature of bipropellant fuel taking into account that the initial temperature of BF– 50 °C, DF – 20 °C:

$$\Delta Q_{БП} = c\cdot m_{БП}\cdot(T_{БП} - T_{ДКП});$$
$$\Delta Q_{ДП} = c\cdot m_{ДП}\cdot(T_{ДКП} - T_{ДП}).$$

As a result of which we have the following:

$$T_{ДКП} = \frac{m_{БП}\cdot T_{БП} + m_{ДП}\cdot T_{ДП}}{m_{БП} + m_{ДП}}. \quad (1)$$

where $\Delta Q_{БП}$ – BF energy loss; $\Delta Q_{ДП}$ – DF energy increment; $m_{БП}$, $m_{ДП}$, $T_{БП}$, $T_{ДП}$ – mass and temperature of BF and DF respectively; $T_{ДКП}$ – temperature of bipropellant fuel.

As you can see from the formula 1 temperature of bipropellant fuel is changed according to the linear law with the change of percentage content of BF in it, provided that input temperature of fuels are stable. (fig.3).

To calculate the viscosity of bipropellant fuel F.R. do Karmo suggested a model on the basis of the corresponding states principle [3]:

$$\nu = \frac{\left(\frac{p_{сум}}{p_1}\right)^{2/3}\cdot\left(\frac{A_{r.сум}}{A_{r.1}}\right)^{1/2}}{\left(\frac{T_{сум}}{T_1}\right)^{1/6}}\cdot\nu_1(T_1, p_1)\times$$
$$\times\left(\frac{\left(\frac{p_1}{p_2}\right)^{2/3}\cdot\left(\frac{A_{r.1}}{A_{r.2}}\right)^{1/2}}{\left(\frac{T_1}{T_2}\right)^{1/6}}\cdot\frac{\nu_2(T_2, p_2)}{\nu_1(T_1, p_1)}\right)^K$$

$$K = \frac{A_{r.сум} - A_{r.1}}{A_{r.2} - A_{r.1}}$$

where ν, ν_1, ν_2, $p_{сум}$, p_1, p_2, $T_{сум}$, T_1, T_2, $A_{r.сус}$, $A_{r.1}$, $A_{r.2}$, – viscosity, pressure, temperature, and molecular mass of a mixture of the first and second fuel respectively.

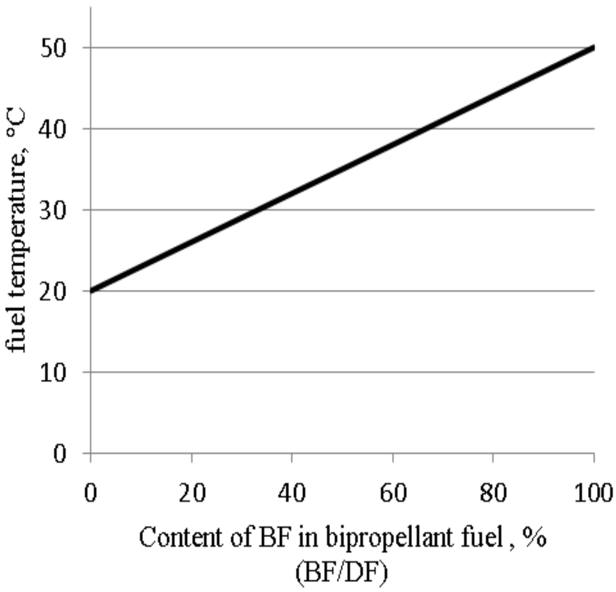

Figure 3: *Temperature of bipropellant fuel depending on the percentage content of BF in it*

After making calculations on the given mathematical model we obtained viscosity index of bipropellant fuel when changing concentration of BF and changing its temperature (Table 1), by this temperature of DF before mixing always was 20 ° C. On Table 1 it is clear that there is such initial temperature of BF at which the viscosity of bipropellant fuel is almost the same for all concentrations of BF in it. These data are shown in Figure 4. The viscosity of pure BF and DF at the appropriate temperatures is the same, but when they are mixed, due to different chemical structure (molecular mass) their joint viscosity increases. The increase is less than one percent that will not significantly affect the engine workflow and reliability.

Figure 5 shows viscosity of bipropellant fuel depending on percentage content of BF in it. Viscosity is changed according to exponential dependence.

Table 1: Dependence of bipropellant fuel viscosity on temperature and percentage content of BF in it.

Temperature of BF / Concentration of BF, %	20	30	40	47,3	50	60	70	80
10	4,32	4,17	4,07	4,01	3,99	3,93	3,88	3,84
20	4,66	4,35	4,14	4,02	3,98	3,86	3,76	3,68
30	5,02	4,53	4,21	4,03	3,97	3,79	3,64	3,52
40	5,40	4,71	4,27	4,03	3,96	3,72	3,53	3,37
50	5,81	4,89	4,33	4,03	3,94	3,64	3,41	3,22
60	6,25	5,08	4,39	4,03	3,92	3,57	3,30	3,08
70	6,72	5,28	4,45	4,03	3,90	3,49	3,19	2,94
80	7,22	5,48	4,51	4,02	3,87	3,42	3,08	2,81
90	7,75	5,68	4,56	4,01	3,84	3,34	2,97	2,68
100	8,31	5,89	4,61	4,00	3,82	3,27	2,87	2,56

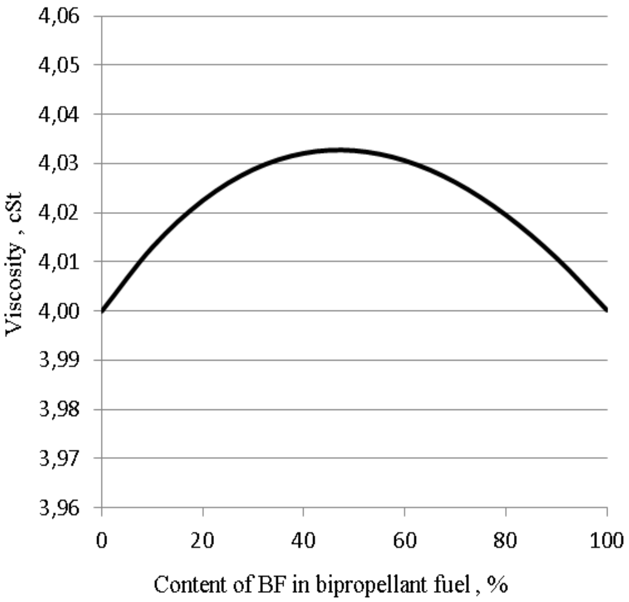

Figure 4: Viscosity of bipropellant fuel depending on percentage content of BF in it at fuels temperature before mixing equals: DF - 20°C, BF – 47,3 °C

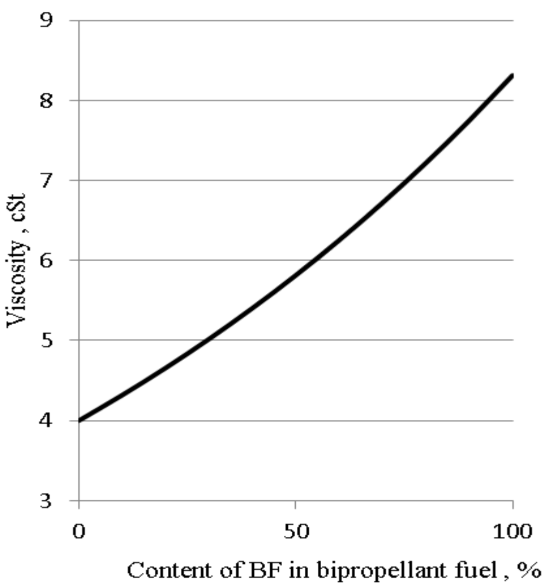

Figure 5: Viscosity of bipropellant fuel depending on percentage content of BF in it (calculated value)

3. Conclusions

Using BF or its mixtures with DF you should take into consideration the increase of fuel viscosity that negatively affects the operation of biodiesel engine. To solve the problem of high viscosity you should install BF heater. As can be seen from the calculations, with the increased temperature of BF to 47,3 ° C its viscosity becomes similar to viscosity of DF. When mixing BF (47,3 ° C) and DF (20 ° C) to different concentrations the viscosity of the mixtures hardly changes - the increase makes less than 1%.

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