Characteristics of heat release in the diesel engine running on biofuel

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Abstract. Research aimed at finding new alternative fuels is becoming more and more urgent with each day, due to depletion of the world’s oil deposits and pollution of the atmosphere with toxic emissions of exhaust gases produced by the internal combustion engine. The article below describes the results of using alternative renewable fuels, such as methyl alcohol and methyl ether of rapeseed oil and their effects on the process of heat generation in diesel engine under various load conditions. The object of research is a 2F10.5/12.0 engine with a dual fuel supply system installed on it. The obtained results showed that the optimal fixing advance angle of fuel injection is equal to 34° to the top dead centre for both types of fuel. The use of alternative fuels does not significantly affect the operational process. At the same time, it was noted that emissions of toxic agents, such as nitrogen oxides and soot, have significantly decreased.

More and more research carried out by modern scientists is aimed at studying alternative fuels [1-17]. This is due to the need to improve the environmental situation and reduce the demand for fossil fuels. For a long time oil has been the only source of raw fuel [18-26]. However, the number of road transport and agricultural machinery is growing every year. Besides, the consumption of petroleum fuel is also increasing, which results in the depletion of oil deposits throughout the world [27-53]. This problem can be solved by using renewable alternative fuels. To get a sufficiently high economic efficiency from the use of new fuels, they must be initially similar in their physical and chemical properties to petroleum fuels [54-71]. This will make it possible not to make significant design changes to existing engines or create specialized engines for a new type of fuel in the future.

Diesel engines are known to be the most tractive due to the fact that the pressure created inside the cylinder of a diesel engine is significantly higher than that of a gasoline engine. This type of engine is able to develop a fairly high power at low rpm. In addition, the above-mentioned engines are the most reliable and durable, which is explained by their design characteristics. Therefore, most agricultural machinery uses diesel engines as a power plant.

Research carried out at the Department of "Heat engines, Automobiles and tractors" at the Vyatka state agricultural Academy has proved methyl alcohol (methanol) to be an advantageous substitute for petroleum diesel fuel. Methyl alcohol (or wood alcohol) can be obtained from the waste of wood processing industry, as well as from almost any gaseous fuel. Owing to this, the cost of methanol is significantly lower than that of diesel fuel.

However, due to the physical and chemical characteristics of methanol, it cannot be used as a fuel for diesels in its pure form. Therefore, it was decided to use it in a diesel with a dual fuel supply system. With that, steady ignition of methanol is provided by simultaneous supply of igniting fuel, which has high rates of self-ignition. For this purpose we proposed to use methyl ester of rapeseed oil (RME),
because in terms of its physical and chemical properties, it is not inferior to diesel fuel, it has a fairly high cetane number and calorific value. In addition, it is a renewable fuel derived from plant materials.

Before the new fuel can come to use in automotive diesel engines, it has to pass a number of tests, including the study of combustion process characteristics in the engine cylinder. For this purpose, a number of bench tests of a 2F 10.5/12.0 diesel engine, upgraded to run on methanol and RME, were conducted on the basis of the VSAA. In this engine, the simultaneous supply of methanol and the igniting RME was provided by means of a dual fuel supply system.

It is possible to describe the process of fuel combustion in the engine cylinder by means of the heat release function, which shows the proportion of heat emitted by a specific time (integral characteristic of heat release χ) or heat release rate (differential characteristic of heat release dχ/dφ). To obtain these dependencies, we performed indexing when the engine was running at various load and speed modes.

Figure 1 shows the diagrams describing the integral law of heat release when the engine is operated at various load conditions and rated speed n=1800 min⁻¹. The presented curves were obtained when the engine was operating under load conditions corresponding to the average effective pressure pₑ equal to 0.115; 0.230; 0.346; 0.461; 0.588 and 0.692 MPa. These curves make it possible to observe how the change in the loading mode of the diesel engine affects the process of fuel combustion in the cylinder.

From the diagram one can see that the operation of the engine at low loads is ineffective, since it is accompanied by incomplete fuel combustion, as the curve χ does not reach one to a considerable extent. This is primarily due to incomplete combustion of methanol, since the cyclic supply of alcohol is low under low load conditions, which leads to depletion of the methanol-air mixture and, as a result, a decrease in the rate of its combustion.

Figure 2 also demonstrates that the differential curve of heat release, which characterizes the intensity of fuel burning out under low load conditions, corresponds to low values. With increasing load and as a result, increasing the cyclic supply of methanol, the methanol-air mixture is enriched and the fuel combustion rate increases. One can also see that at high load conditions, the integral characteristic of heat release tends to reach one, which indicates a more complete combustion of fuel and better efficiency of the engine.
Figures 3 and 4 show similar diagrams, but they are relevant for operation at the speed corresponding to the maximum torque mode n=1400 min\(^{-1}\). It is also evident from the diagrams that at low loads the intensity of heat release is low, which in turn results in incomplete fuel combustion.

**Figure 2** – Differential characteristics of heat release at n=1800 min\(^{-1}\)

**Figure 3** – Integral characteristics of heat release at n=1400 min\(^{-1}\)
As a result of the research, the following conclusions can be drawn. The efficiency of the combustion process when running a diesel engine on methanol and RME depends on the operating mode in many respects. It is specified that the engine running on these alternative fuels demonstrates better economic performance at higher load conditions. This was also confirmed by the displacement of the maximum efficiency towards high loads. One should take into consideration the presence of oxygen in methyl alcohol and RME, which contributes to more complete combustion of these fuels at high loads while working on diesel fuel deteriorates the combustion efficiency due to lack of oxygen in the combustion zone. However, at low loads, on the contrary, there is a decrease in the efficiency of the engine due to peculiarities of the combustion process of the methanol-air mixture. These aspects should be taken into account when using methanol and RME as fuel for diesels.

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