Use of bio additives in diesel engine fuels

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Abstract. The use of fuel additives in various engines improves their performance. In particular, biodiesel is considered to be a good additive in diesel fuel. It is one of the alternative fuels used in diesel engines. The use of this type of fuel is also of strategic importance in the development of the economy of the countries. The main problem is to find the optimal ratio between biofuel and conventional diesel fuel in the mixtures injected into the engine cylinders. One of the advantages of biofuel is that it significantly reduces the amount of harmful emissions from engines - especially CO and HC. Along with this advantage, there is an increase in nitrogen oxides, which are released during the combustion of the mixture of the bio-additive and ordinary diesel fuel. Many of the challenges facing the use of biofuels are related to the reduction of NOX. Exhaust Gas Recirculation (EGR) is also used to reduce them. Key words: biodiesel, harmful emissions, Exhaust Gas Recirculation.

1. Introduction

Toxic components - Nox, HC, CO, PM, etc. emmit from internal combustion engines which have good thermal efficiency. These components are dangerous to humans, which requires the establishment of control over them. This contributes to the use of other sources of chemical energy, such as the use of biofuels or bioadditives in diesel engines. The bioadditive is produced from vegetable oils and is very good when used as a fuel for diesel engines. A significant advantage is that when working with it does not require a change in the design of the engine itself, which makes it practically usable in all types of diesel engines.

It significantly reduces the toxic components in the engine exhaust. There is a decrease in dust particles (PM), CO and HC. The operation of the engine with such a mixture is stable, the crankshaft speed is stable. Major manufacturers of diesel engines are the EU, USA and Japan. One of the modern trends in the development of the engine industry is the increase in the production of diesel engines and the scope of their application. They have become especially popular in heavy-duty cars, buses and tractors, and now in many cars.

The above circumstances require that conventional diesel fuel be gradually replaced by other fuels or additives to be used in internal combustion engines. But "new" fuels must also be environmentally friendly. Biodiesel is one of the alternative fuels that is increasingly used in internal combustion engines [6,7,8,9,10,11].
2. Exposition

A serious drawback in the operation of the engine with conventional diesel fuel is the increased release of NOx (nitrogen oxides). If we compare the engines running on both types of fuel - with the addition of biodiesel and conventional fuel [1,2,9] it is found that the one that runs on conventional diesel fuel has a higher NOx release.

One of the methods for reducing NOx in harmful emissions is the use of exhaust gas recirculation. The use of the Exhaust Gas Recirculation (EGR) system is one of the effective ways to help reduce nitrogen oxides. This method is also used for engines running on both conventional diesel fuel and those running on biodiesel additives. This NOx reduction system has been in use since the 1970s, but has been continuously improved by improving the engine's electronic injection control systems. A lower combustion temperature in the combustion chamber is required to control the NOx emissions and reduce them. Diesel engines run on excess air, they emit more smoke and when using EGR fuel consumption decreases, but increases HC, PM and CO. The specific fuel consumption increases slightly. Systems using EGR are very efficient in heavy-duty engines. When using EGR, NOx decreases, but smoke and RF levels increase. Experimental tests [3] with a 9.0 kW engine and direct fuel injection (DI) investigated the effect of mixing exhaust gases with CO2 and N2. It has been found that the addition of CO2 to the total mixture leads to a reduction in NOx emissions, but increases the percentage of unburned hydrocarbons (UBHC).

In the construction of a 3D model, which examines the effect of the use of EGR, it is seen that a motor running on a forced-compressor compressor affects the thermal efficiency at maximum pressure in the combustion chamber, but reduces O2 as a result of low emissions. NOx. The use of EGR requires cooling of the exhaust gases to obtain low NOx values, which affects the increase of smoke emissions, but does not affect the efficiency of the engine at high gas flow rates through the EGR valve.

In a similar study with a single-cylinder engine at different values of open state of EGR, fuel pressure, injection time, temperature of the incoming air and the way they affect the exhaust gases:

- EGR can adversely affect the formation of smoke, as it lowers the average combustion temperatures and reduces the amount of incoming oxygen, which in turn prevents the formation of soot;
- NOx emissions are reduced in proportion to the change in the temperature ratio of the incoming air;
- at a given level of oxygen concentration, the cooling of the EGR reduces more NOx with less opening of the EGR valve than if this system is not cooled;
- NOx emissions change significantly [4].

This article aims to study some of the effects of exhaust gas recirculation with oilseed esters, such as a mixture of biodiesel and conventional diesel.

Sunflower oil is one of the main crops used to produce biofuels and as an additive to ordinary diesel fuel. The method of processing the raw material is called transesterification and is a chemical process of converting large branched triglyceride molecules of vegetable oils and fats into straight, small chains. These chains react to alcohol mixtures (such as methyl esters), with methanol being preferred because it is not hygroscopic but is more expensive than other alcohols. A number of studies have shown that the optimal ratio for obtaining a biomixture of 1 liter of sunflower oil using methanol and NaOH is 0.2L (0.08 kg) [2]. The parameters of ordinary diesel fuel, sunflower oil and sunflower oil methyl ester (SFMF) are shown in Table. 1
Table 1. Indicators of ordinary diesel fuel, sunflower oil additive and SFMF.

| Parameters                              | Ordinary diesel fuel | Sunflower oil additive | SFMF  |
|----------------------------------------|----------------------|------------------------|-------|
| Kinematic viscosity at 38°C (mm²/s)    | 2.7                  | 34.0                   | 37.1  |
| Density (kg/m³)                        | 840.0                | 960.0                  | 878.0 |
| Calorific value (MJ/kg)                | 42.5                 | 36.5                   | 38.5  |
| Flaming temperature (°C)               | 52.0                 | 276.0                  | 224.0 |
| Cetane number                          | 47.0                 | 37.0                   | 58.0  |

In principle, the use of EGR is used to mix the oxygen and nitrogen contained in the fresh air charge entering the engine cylinders with carbon monoxide and water vapor from the engine exhaust. This results in the reuse of the latter at the motor inlet (Figure 1).

![Figure 1. Exhaust gas recirculation system (arrow points to valve command) implemented on a Mercedes engine.](image)

This leads to an increase in the specific heat capacity of the mixture and reduces the oxygen concentration in it. In this way the main goal of the recirculation is achieved - significant reduction of NOx. The opening of the EGR valve is measured in % and depends on the mass of the exhaust gas recirculation in the total volume of the incoming fresh air charge:

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EGR = \left\{ \frac{\text{Mass of air admitted without EGR} - \text{Mass of air admitted with EGR}}{\text{Mass of air admitted without EGR}} \right\} .100, \text{ (%)}
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When there is a different percentage of open state of the EGR valve, different values of smoke and concentration of nitrogen oxides in the exhaust gases are observed. When the EGR is running, higher values of smoke in the exhaust gases are observed, compared to the operation of the engine without
EGR. Smoke increases with increasing engine load and EGR operation. The opening of the EGR leads to a decrease in the amount of oxygen entering the engine and is the reason for incomplete combustion, increased formation of PM, but also to a decrease in the amount of nitrogen oxides in the exhaust gases.

Figure 2 shows the change in the specific fuel consumption depending on the engine load during its operation with and without EGR as well as the effect of the use of the biofuel additive (in this case B15). Specific fuel consumption decreases with increasing load more when using EGR than if it is not used. Also at higher loads the specific consumption is almost the same when using biofuel and EGR, as well as its operation without the use of EGR. There is an increase in specific fuel consumption with increasing amount of biomixture in diesel fuel when running the engine with EGR. This result is due to the lower calorific value of sunflower methyl ester, comparing it to engine performance with and without the use of EGR. There is also an increase in specific fuel consumption of about 15% [4] when using biofuel at full engine load and operating with EGR.

![Figure 2. Change in specific fuel consumption depending on engine load with and without EGR and B15 operation.](image)

![Figure 3. Variation of the thermal efficiency of the engine depending on its load and fuel B15.](image)
Figure 3 shows the dependence of thermal efficiency on engine load when using conventional diesel fuel and biomixtures of sunflower oil esters. The tests were performed with and without the use of the EGR valve. The figure shows that the increase in load during EGR operation is less due to the use of reburning carbon, which enters the combustion chamber together with the exhaust gas recirculation. At maximum load, the thermal efficiency does not change and does not depend on the exhaust gases.

Thermal efficiency is improved by increasing the concentration of biofuel additive in the mixture, due to the higher degree of oxygen in biofuels. It was found that when a mixture of B20 when working with EGR in the open state by 15%, increases by 4% of thermal efficiency, but at lower engine load. This is not observed when using diesel fuel without EGR [3].

3. Conclusion

The report analyzed experiments performed with a diesel engine running on conventional diesel fuel and a biodiesel additive, as well as its operation with and without EGR. The results obtained can be summarized briefly as follows:

- The amount of NOx in the exhaust gas decreases by about 25% when the engine is running on biodiesel and the EGR is 15% open. This is due to the lower amount of oxygen contained in the exhaust gas. As a result, the temperature in the combustion chamber decreases.
- Sunflower methyl ester when working with EGR in the open position degree of 15% improves the thermal efficiency by 4%.

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