Considerations on pollution from the use of biofuels

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Abstract. While, for thousands of years, natural pollution has reversible effects on environment, thanks to biological and biochemical cycles, the artificial pollution produced by industrial activities disturbs natural cycles and in most cases has irreversible consequences. Among the most polluting vehicles made by humans, we find the vehicles equipped with internal combustion engines. In the past decades, global automotive vehicles manufacturing has reached a high level thanks to his positive impact on people mobility. Therefore, reducing exhaust gas emissions from internal combustion engines represent a research topic for specialists around the world. The use of biofuels is a promising research direction. The EU authorities has issued different sets of standards for the harmful emissions that affect the quality of the environment. In this paper we present the results obtained in the laboratory using different biodiesel concentrations at different load and speed regimes.

1. Introduction

The use of biofuels to power internal combustion engines has generated enthusiasm among automotive manufacturers. Although it was initially thought that the pollution issues had been resolved, it was found later that the production and use of these fuels also had negative effects:

- social effects:
  - the manufacture of bioethanol (Brazil) has led to an increase in the price of sugar;
  - the use of cereals as a raw material for the manufacture of ethanol can generate a food crisis, especially in poorly developed countries;
  - the soil has degraded as a consequence of monoculture and excessive use of fertilizers, herbicides and pesticides to obtain large productions;
- pollution with gas emissions in the atmosphere:
  - internal combustion engines equip over 800 million automobiles and other transport vehicles; the compression-ignition engine is considered to be a major pollutant with gas emissions and particulate matter;
  - road transport produces the highest pollution with gas emissions and particulate matter (including the dust lifted of the roads).

Experimental researches has confirmed the possibility of using fuels obtained from vegetable and animal oils to power compression ignition engines. Were used Diesel fuel and biofuel in a concentration of 100% as well different diesel-biofuel mixtures indicated as B10... B50 depending on the percentage of biofuel in the mixture. The measurements were performed on the stand in the Engine Laboratory of the University of Craiova. The used engine was adjusted to different speeds and loads, determining the consumption and composition of the burnt gases.
2. Pollutants, objectives and standards
Depending on how it is produced, pollution can be:

- physical pollution of a thermal nature:
  - the steam discharge, hot and boiling water, heat radiation;
  - the noise pollution caused by the transport vehicles and industrial activities for their manufacture;
  - the emissions of burnt gases produced by internal combustion engines but also by thermoelectric power plants and other industrial activities;
- chemical pollution - produced by the chemical plants by the discharge of polluting substances resulting from the technological processes, the excessive use of fertilizers and chemical treatments, oil residues;
- biological pollution: residues from food industry, pathogens from animal manure;
- radioactive pollution: difficult to detect and with severe effects on the health of the living world.

It can be seen that the electricity generation sector is the sector that produces the highest level of pollution (figure 1).

![Figure 1. Greenhouse gas emissions in European Union [1].](image)

Therefore, when it is proposed to use electric cars as a solution to reduce pollutant emissions, should be taken into account those electricity generation technologies that produce less pollution compared to internal combustion engines in order to comply the EU air quality standards (table 1).
Table 1. WHO report regarding the air quality.

| Pollutant | Period | mg/m³ according to WHO guidelines | mg/m³ limit values according to EU Directive on ambient air quality | The number of authorized exceedances per year, according to EU standards |
|-----------|--------|----------------------------------|---------------------------------------------------------------|------------------------------------------------------------------|
| NO₂       | 1 year | 40                               | 40                                                           | -                                                                |
|           | 1 hour | 200                              | 200                                                          | 13                                                               |
| O₃        | 8 hours| 100                              | 120                                                          | 25                                                               |
| PM₁₀      | 1 year | 20                               | 40                                                           | -                                                                |
|           | 24 hours| 50                               | 50                                                           | 35                                                               |
| PM₂.₅     | 1 year | 10                               | 25                                                           | -                                                                |
|           | 24 hours| 25                               | -                                                            | -                                                                |
|           | 24 hours| 20                               | 125                                                          | 3                                                                |
| SO₂       | 1 hour | -                                | 350                                                          | 24                                                               |
|           | 10 min.| 500                              | -                                                            | -                                                                |

Source: WHO Air quality guidelines (2005) and AAQ Directive 2008/50/EC [2]

3. Stand for experimental research

The experimental researches was carried out on an experimental stand located in the INCESA Laboratory at the University of Craiova which is equipped with a DEUTZ F4L912 engine, a compression ignition engine with direct fuel injection (figure 2).

It have been used Diesel-biofuel mixtures with different mixing ratios.

Table 2. Elemental analysis for different biodiesel compositions.

| Fuel          | Oxygen (%) | Hydrogen (%) | Carbon (%) | Nitrogen (%) | Total (%) |
|---------------|------------|--------------|------------|--------------|-----------|
| Diesel        | 1.6        | 11.9         | 86.4       | 0.1          | 100       |
| 10% Biodiesel | 2.89       | 11.81        | 85.09      | 0.22         | 100       |
| 20% Biodiesel | 3.87       | 11.21        | 84.48      | 0.44         | 100       |
| 30% Biodiesel | 5.5        | 11.60        | 82.24      | 0.66         | 100       |
| 40% Biodiesel | 5.03       | 11.53        | 82.56      | 0.88         | 100       |
| 50% Biodiesel | 5.85       | 11.45        | 81.60      | 1.1          | 100       |
| 100% Biodiesel| 10.02      | 10.98        | 76.8       | 2.2          | 100       |

For each fuel composition used, were performed calculations to determine the air required for combustion as well as the composition of the burnt gases under the conditions of theoretical-complete combustion [3].

For the presented paper work we have considered the results of experimental researches that represent the real operating situations of a compression ignition engine powered by various mixtures of diesel and biofuel. Knowing the elemental composition of the used fuels allows us to estimate the engine performance as well as the composition of the burnt gases. If we analyze only the carbon content (table 2) we can estimate approximate values of carbon dioxide in the gases emitted into the atmosphere under conditions of complete combustion. It has been observed that in the case of using biofuel without mixing with diesel fuel has been achieved a significant reduction in emissions of Carbon Dioxide. In the same time, pure biofuel has a high percentage of nitrogen, which leads to an increase of nitrogen oxides in the burnt gases (table 2).

4. Experimental researches

The DEUTZ engine has been tested under different load regimes that have been customized by measuring brake power. Fuel mixtures with different diesel-biofuel compositions were used. It was
collected samples from the burnt gases and their composition was determined. The research results were presented graphically and tabular.

**Figure 2.** Stand for experimental research:
a – fuel tank; b – electronic balance; c – fuel pipes; d – display parameters; e – compression ignition engine DEUTZ.

**Table 3.** Oxygen excess in the burnt gases.

| Engine power (kW) | Fuel  |
|-------------------|-------|
|                   | 100D  | B10 | B20 | B30  |
| 0.5               | 16.6  | 16.8| 16.85| 17.3 |
| 1.0               | 16.55 | 16.6| 16.8 | 17.25|
| 1.5               | 16.4  | 16.2| 16.7 | 17.15|
| 2.0               | 15.8  | 16.15| 16.6 | 16.9 |
| 2.5               | 15.75 | 15.6| 16.5 | 16.4 |
| 3.0               | 15.6  | 15.5| 16.4 | 16.3 |
| 3.5               | 14.8  | 14.9| 16.3 | 16.2 |
The oxygen composition of biofuels is higher comparing with diesel fuel. This increase of oxygen composition was observed regardless of the vegetable oil used to obtain the biofuel. If we analyze the composition of the burnt gases, for a correct regulation of the excess air for each biodiesel composition, we found small differences in the oxygen content in the burnt gases for different diesel-biofuel compositions (table 3) [4, 5].

From the graphical analysis it can be observed that in the case of 10% biofuel composition the differences are insignificant, which allows us to keep the engine settings from running on diesel fuel. The influence of the load on the brake can be observed: the amount of oxygen in the burnt gases composition decreases, this fact being explained by the enrichment of the mixture (figure 3) [6].

![Figure 3. Variation of oxygen emissions in burnt gases.](image)

From the elemental analysis (table 3) it is observed that the highest value (86.4%) of the carbon content is for diesel fuel and the lowest value (76.8%) is for 100% biodiesel. From the experimental research carried out on the stand, was found that in the case of increasing the percentage of biofuel in the mixture, the fuel mixture consumption increase accordingly [7].

| Table 4. Carbon dioxide emissions. |
|-----------------------------------|
| **Fuel** | 100D (%) | B10 (%) | B20 (%) | B30 (%) |
|________|___________|___________|___________|___________|
| Engine power (kW) | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 |
|________|___|___|___|___|___|___|___|
| 100D | 4.01 | 4.6 | 5.4 | 6.01 | 6.5 | 6.7 | 6.9 |
| B10 | 3.6 | 3.8 | 4.01 | 4.6 | 5.2 | 5.8 | 6.7 |
| B20 | 2.0 | 2.2 | 2.5 | 2.6 | 2.4 | 2.6 | 2.9 |
| B30 | 2.0 | 2.2 | 1.4 | 2.6 | 2.5 | 2.6 | 2.8 |
As can be seen from table 4 and figure 4, when the percentage of biofuel in the fuel mixture increases, the level of carbon dioxide emissions decreases. For higher values of biofuel content (20%, 30%) it can be observed a small variation of the level of carbon dioxide emissions depending on the level of brake loading.

For all types of internal combustion engines, Spark Ignition Engine or Compression Ignition Engine, are being made researches and design efforts to eliminate unburned hydrocarbons from the exhaust gases [8].

The reduction of hydrocarbon emissions can be achieved by improving the fuel mixing and supplying systems [9]. The level of unburned hydrocarbons in the exhaust gases has been significantly reduced by using of state-of-the-art injection pumps and injectors [10, 11].

The use of biodiesel in a mixture with diesel had the effect of a substantial reduction in hydrocarbon emissions (by up to 60% in the case of the B30 mixture, for a power of 0.5 kW) – table 5, figure 5.

### Table 5. Hydrocarbons in the burnt gases.

| Engine power (kW) | 100D (ppm) | B10 (ppm) | B20 (ppm) | B30 (ppm) |
|-------------------|------------|-----------|-----------|-----------|
| 0.5               | 69         | 48        | 38        | 28        |
| 1.0               | 58         | 46        | 38        | 27        |
| 1.5               | 53         | 45        | 36        | 26        |
| 2.0               | 52         | 42        | 38        | 25        |
| 2.5               | 50.5       | 41        | 28        | 25        |
| 3.0               | 45         | 40.5      | 26        | 25        |
| 3.5               | 44         | 38        | 26        | 25        |
The presence of carbon monoxide in the burnt gases is due to the supply and air-fuel mixture formation installation and the combustion process. Applying the post burning solutions (by using catalysts) has been achieved the reduction of Carbon Monoxide, see EURO 5 and EURO 6 standards.

The presence of carbon monoxide in the burnt gases is due to incomplete combustion or faulty adjustment of the fuel supply and mixture formation installation. By using post burning solutions (oxidation catalysts) the CO level has been reduced.

In the case of using different diesel and biodiesel mixtures, can be observed a reduction of carbon monoxide emissions of up to 48% at low power (0.5 - 2.0 kW) and a decrease of up to 33% of these emissions for higher power values (2 - 3.5 kW) – table 6, figure 6.

**Table 6.** Carbon monoxide emissions.

| Engine power (kW) | 100D (%) | B10 (%) | B20 (%) | B30 (%) |
|-------------------|----------|---------|---------|---------|
| 0.5               | 0.15     | 0.082   | 0.15    | 0.078   |
| 1.0               | 0.122    | 0.078   | 0.078   | 0.06    |
| 1.5               | 0.079    | 0.072   | 0.07    | 0.04    |
| 2.0               | 0.042    | 0.039   | 0.042   | 0.032   |
| 2.5               | 0.044    | 0.028   | 0.04    | 0.03    |
| 3.0               | 0.045    | 0.03    | 0.031   | 0.03    |
| 3.5               | 0.045    | 0.03    | 0.03    | 0.031   |

**Figure 5.** Hydrocarbon emissions.
Modern technologies implemented to meet the EURO 5 and EURO 6 requirements have allowed a significant reduction in CO and NOx emissions (figure 7).

5. Conclusions
The operation of compression ignition engines using biodiesel is more efficient for reducing environmental pollution. The quantities of greenhouse gases released into the atmosphere are smaller comparing with operation on diesel (figure 3, figure 4, figure 5 and figure 6).

Experimental researches conducted on the stand confirms that the quantities of pollutants such as CO2, HC, and CO are lower comparing with operation on diesel, but if we consider the higher
consumption in the case of using biofuels, it can be said that the amounts of pollutant emissions evacuated in the environment are significantly equal.

Numerous elemental analyzes were performed for biodiesel composition (10%, 20%, 30%, 50% and 100%) and a high oxygen content was found in the composition, which will assure a better combustion in the engine but also the susceptibility of this type of fuel for oxidation. This finding involves special storage requirements for the biofuels and the using of antioxidant additives for their stability.

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