# Behavior Of Combustion Gases Generated By An Internal Combustion Engine Using Diesel And Biodiesel

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**Abstract:**

Biodiesel is a type of mineral oil with gas emissions during the combustion process better than diesel. Environmental and commercial quality would be one of these improvements in vehicular and stationary engines. This paper studies an internal combustion engine stationary vehicle fueled by diesel-biodiesel blends in the test in order to analyze the different gas emissions from the combustion. In these study analyzes the best balance to find the emissions that meet the goals of the control agencies such as the Environmental Protection Agency (EPA) of the United States and of National Environmental Council (NEC) of the Brazil. The nitrogen oxide levels and the main engine exhaust gas pollutants are extracted to quantify and compare. Among these gases, carbon dioxide, which inducing global warming. The methodology used in the measurement of gases is performed by the control unit "Discovery-G4" compound. This analysis is done on the engine power of 110 kVA the diesel cycle, varying its rotation at intervals of 200 rpm. The initial rotation is 1000 rpm up to 1800 rpm. In all analyses rotation, the binary of the fuel mixtures are D93B7, D80B20, D50B50 and pure biodiesel B100. The performance of the emissions of the following gases: CO (carbon oxide), HC (hydrocarbons), NOx (nitric oxide and nitrogen dioxide), $CO_2$(carbon dioxide) e $O_2$ (oxygen) and materials particulates were measured. In the current environmental scenario, we can mention two possible paths. The first would be the current modes of transportation in Brazil that are structured in internal combustion engines, which proves, on average, increasing rates of emissions per unit of energy consumed with reported problems. Of course, additional efforts may bring significant reductions in these rates with structural changes in freight transport means in the direction on greater participation of railways and waterways. The second ay would be the generation of electric power generators in group units using internal combustion engines as the primary machine.

**Keywords**: Gas emissions, Diesel, Biodiesel Blends.

## 1. Introduction

The energy consumption in Brazil shows that oil products tends to decrease in the transport sector compared to other sectors in $CO_2$ emissions. In the case of natural gas, which has lower emission factors than other fossil fuels, the emissions percentage is likely of increase.

The graph of Fig. 1 presents estimates of the future key sectors in the country's economic growth that make irreversible the increase of gas emissions and assumes as the efficient use of energy. Sectors of industry and transport estimated in the National Energy Balance (NEB) from 2005 to 2030 are the largest contributors in emissions. Both currently use oil products.

In the transport sector, the reduction of $CO_2$ emissions envisions the use of pure biodiesel as a substitute for oil products such as diesel [7]. This renewable fuel source, whose raw materials soybean oil (around 68.6 %), was deployed from 2005. Table 1 [8] shows important sectors in economic growth using biodiesel from of its implementation.

It is noted that the significant growth the biodiesel occurs from 2008 the fact that a mandatory blend of pure biodiesel (B100) in diesel oil , going from 2% (D98B2) between January and July , 3% (D97B3) July 2008 to June 2009 and 4% (D96B6) in November 2009 .

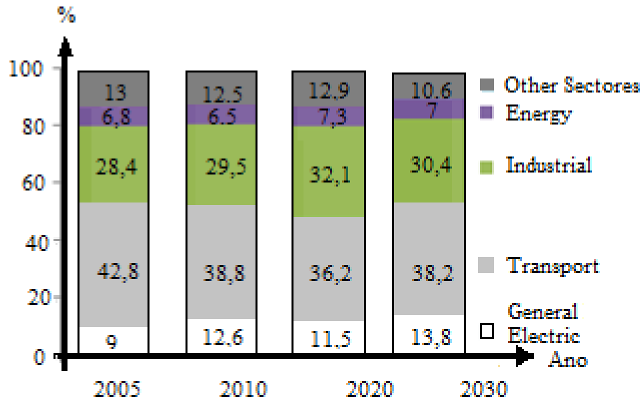


*Fig.1. Carbon dioxide emissions in productive sectors (million $TCO_2$).*

*Table 1. Biodiesel production flow in some sectors ($10^3m^3$) in the years 2005 to 2013*

| **FLUXO** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
|---|---|---|---|---|---|---|---|---|---|
| PRODUÇÃO | 1 | 69 | 404 | 1.167 | 1.608 | 2.397 | 2.673 | 2.717 | 2.917 |
| TRANSPORTES | 1 | 69 | 404 | 876 | 1.228 | 1.864 | 2.098 | 2.222 | 2.364 |
| RODOVIÁRIO | 1 | 68 | 396 | 858 | 1.202 | 1.825 | 2.039 | 2.161 | 2.304 |
| INDUSTRIAL | 0 | 0 | 0 | 22 | 29 | 36 | 59 | 62 | 68 |
| OUTROS | 0 | 0 | 0 | 4 | 5 | 8 | 11 | 11 | 12 |

With the constant increase in the production of the vehicles, pollution indices converge to an increase in emissions. The products of combustion from the burning fuel produce some pollutants and emissions released into the atmosphere as particulates emissions, which are aggravating of the environment.

Among these emissions and particulate matter, the Fig. 2 shows the complete and incomplete combustion processes with their gas components in internal combustion engine. The Gas emissions in the carbon monoxide is highly toxic, carbon presents itself in the form of smoke , THC (TotalHC) is formed by fractions of particles of fuel [2].

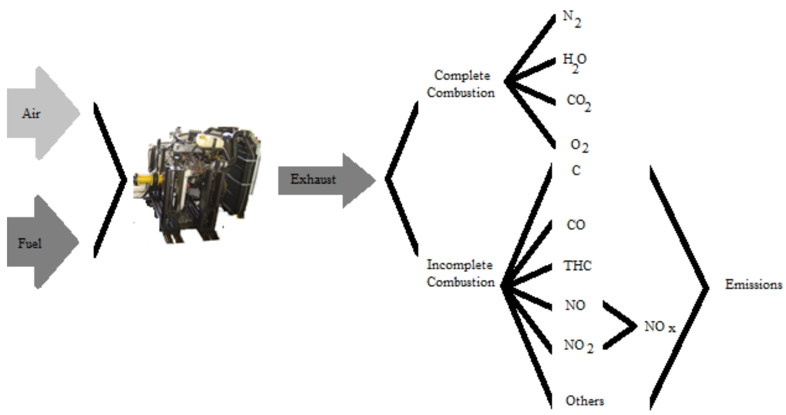


*Fig. 2. Products of combustion in internal combustion engines.*

The percentage of emissions should be monitored and that there laws that impose criteria [2], the legislation consists of three pillars: test, procedure and limits. Laws related to engines of the tests are characterized by the profile a rotation and torque.

The Legislation in Brazil, from the Resolution Number 18 of May 6 1986, the National Environmental Council [9] creates the Control Program of Air Pollution from Motor Vehicles [10]. There are two key points in the program. The first is the reduction of the emission levels of pollutants by motor vehicles in the attainment of air quality standards and second, to promote the improvement of the technical characteristics of liquid fuels in order to decrease emissions in the environment.

For engines of the diesel cycle (light or heavy) , the first phase of Control Program of Air Pollution from Motor Vehicles established the maximum in values soot emission in exhausts, from October 1987 [9]. In the latest phase [11] it was agreed that from January 2012, emissions would gain new limits, as Table 2.

*Table 2. Pollutant gases emission levels from the heavy automotive exhaust*

| Test | Emissions (g/Km) | | | |
|---|---|---|---|---|
| | NOx | HC | CO | Particulate Materials |
| CCR/CLR | 2 | 0,46 | 1,5 | 0,02 |
| ETC | 2 | N.A. | 4 | 0,03 |

The heavy vehicle classification, according to the resolution of National Environmental Council, characterized by road vehicle the from passenger, freight or mixed use with a capacity exceeding 2.8T. The European Cycle Load Response (CLR) consists of a sequence of four constant rotation levels and loads increasing in determining the opacity of the exhaust emission. The European Cycle Constant Regime (CCR) consists of a test cycle with thirteen operating modes.

The European cycle Transient Regime (ETC) consists of eighteen hundred transient modes, second by second, simulating real conditions of use. The hydrocarbon HC gas is not applicable (NA) at this cycle

# 2. The Process of Combustion Engine and Emissions

## 2.1. Product of Combustion

The Internal combustion engines fueled with oil or its derivatives form products depending on the emission levels which can cause damage to the environment in which we live. The chemical reaction that occurs in the combustion process, the links of reagents are broken and the atoms if electrons reorganize to form the product. The combustion elements undergo oxidation of the product , releasing energy . The element of combustion undergoes oxidation of the result of burning fuel to release energy in the final result. A small percentage of electromagnetic energy (brightness), electricity (ions and free electrons) and mechanical energy (noise) are released during the combustion process.

Regarding various chemical elements constituting combustion in most common fuels are: carbon, hydrogen and sulfur. Sulfur is a component that has no importance in the energy release, but presents problems important pollution and corrosion.

The combustion becomes complete when the carbon present the burning in the form of carbon dioxide, hydrogen present the burning in the form of water and burning sulfur in the form of sulfur dioxide. The remaining fuel elements are oxidized. If these conditions are not met, the combustion is considered incomplete [3]. The Equation (1) shows chemical reaction of complete combustion to a fuel containing carbon (C), hydrogen (H) and oxygen (O) [4].

$$C_\alpha H_\beta O_\gamma + \left(\frac{\alpha+\beta}{4} - \frac{\gamma}{2}\right)(O_2 + 3.76N_2) \rightarrow \alpha CO_2 + \left(\frac{\beta}{2}\right)H_2O + 3.76(\alpha + \frac{\beta}{4} - \frac{\gamma}{2})N_2 \qquad (1)$$

Fuel + Air → Combustion

The parameters α, β and γ are carbon numbers, hydrogen and oxygen in the fuel molecule.

## 2.1. Emissions of Combustion

The emissions analysis is widespread in the academic and is in the scientific literature. Costa and other authors [6] make a study of energy efficiency, the operating with biodiesel and natural gas the in internal combustion engine in rotation of 1800 rpm. Tests are performed on B10 blends to pure biodiesel (B100). The main objective of this study is the need to know the behavior of greenhouse gases in order to reduce pollutants the atmosphere.

Another work that makes the analysis of the use of biodiesel blend is ALNEFAIE and other authors [1]. In this paper, there is the opportunity of using almond oil at source of renewable and alternative fuel in mixtures of D90B10 (10% of the biodiesel) , D70B30 (30% of the biodiesel) and D50B50 (50% of the biodiesel) in order to measure the performance with new parameters to be discovered and influence of these mixtures on exhaust emissions. The internal combustion engine operates at a rotation of 1500 rpm.

In order to study the behavior of emission of exhaust gases in internal combustion engines with compression ignition direct injection, this study aims to analyze the emission profiles at different combinations of binary fuel: diesel and biodiesel. Observing the behavior of the engine efficiency and the levels of particle release and the opacity to a long range of engine rotation.

In this work, the analysis of emissions is performed with changing the test engine operating fuel. The partial biodiesel blends with diesel oil that starts from 5% biodiesel with 95% diesel oil, and ends with pure biodiesel (B100).

# 3. Tests and Measurements

The calculations involving gaseous fuels are based on the volume, while liquids and solid calculated are based on mass [5]. In the analysis of $CO_2$, CO and $O_2$, the values are obtained by volumetric chemical analysis in PC-multigas analyzer, and a gas analyzer Opacity NA9000. The monitoring of gases is accomplished through software that provides details of the measurements.

The engine compression ignition (ICO) under study is a MWM 2.8 SPRINT model 4.07TCE, presenting gases with concentrations of pollutants larger than those found in vehicle engines type ignition spark.

When starting the test is performed a visual inspection of technical equipment constituting the system of command and control, for in the next moment, starting the engine operating with fuel selected. The data collection for the analysis is done after the engine achieve operating regime and recommended temperature. Four fuel samples are selected for testing with following proportions: D95B5 (5% of the biodiesel), D80B20 (20% of the biodiesel), D50B50 (50% of the biodiesel) and B100.

The Internal combustion Engine of compression ignition to the studying is attached to a dynamometer, the structure these is entire mounted on a bench of test. The workbench allows the engine operating control system operating variables take effect. The dynamometer used is the electric LOGS, which determines torque values , power and load for certain rotations in the study.

The measurement of the fuel is performed by the gravimetric method. The fuel storage system is a decanting funnel, or separation, with a capacity of two liters of fuel and balance of Balmak ELC -25 with measuring capacity of 25 kg and precision of 2g. Fig. 3 shows the experimental equipment, specifying the operating variables recorded during the test.

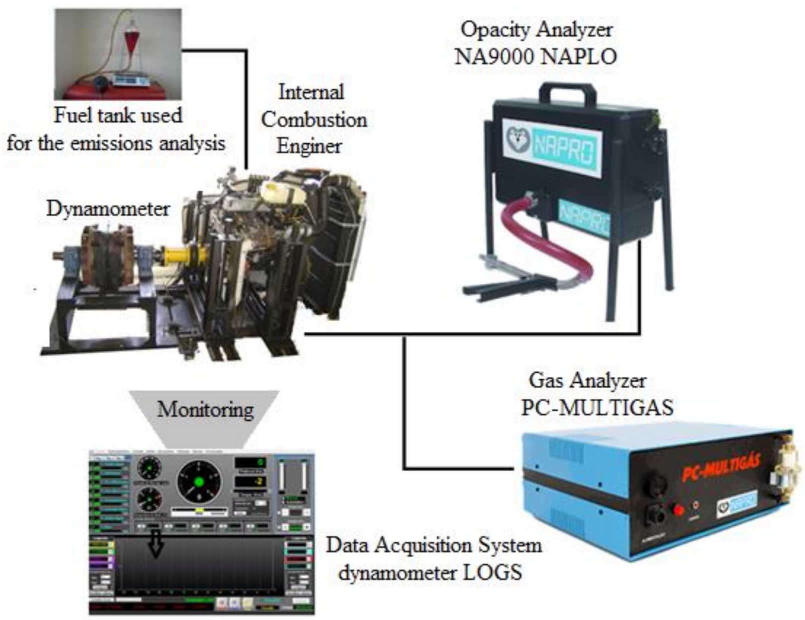


*Fig. 3. Test structure for biodiesel blends.*

## 4. Emissions Behavior and Conclusions

Measurements of gas started to 1000 rpm, plus 200 rpm every new test to the value of the 1800 rpm. Measurements were performed with eight 60s intervals from one measurement to another for each rotation cycle. With the acquired values, calculated averages were then performed to obtain the values of the concentrations of major pollutants.

The numbered figures four to of five represent data obtained from the analysis off emissions.

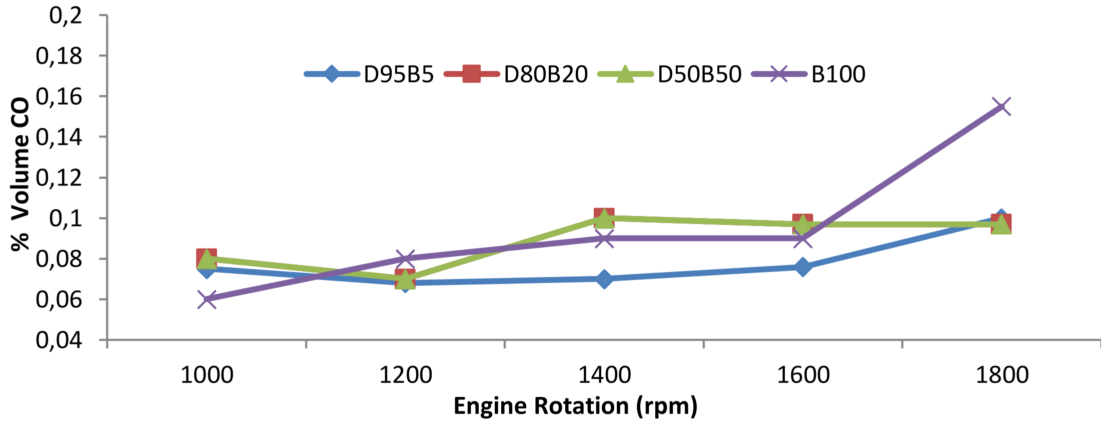


*Fig. 4. Emissions of CO in mixtures of Biodiesel.*

In the graph of Fig. 4, all biodiesel blends produces carbon monoxide gas with similar percentages. Upon reaching the rotation of 1600 rpm, pure biodiesel moves away from the values others.

The pure biodiesel moves away the from other mixtures of rotation in of 1600 rpm carbon dioxide gas, as shown in Fig. 5.

In Fig . 6, the quantity of oxygen is greater in every rotation of B100.

The B5 and B100 values in Fig. 7 shows similarities with increasing engine speed for hydrocarbon gases.

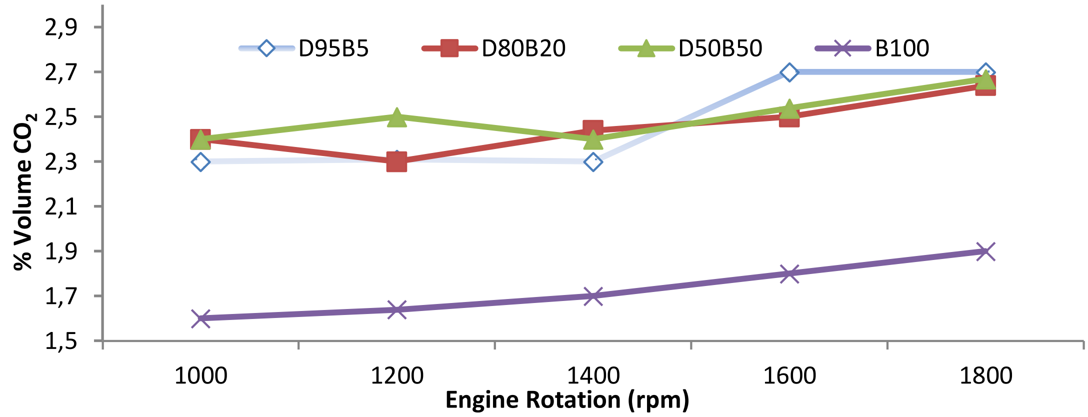


*Fig. 5. Emissions of $CO_2$ in mixtures of Biodiesel.*

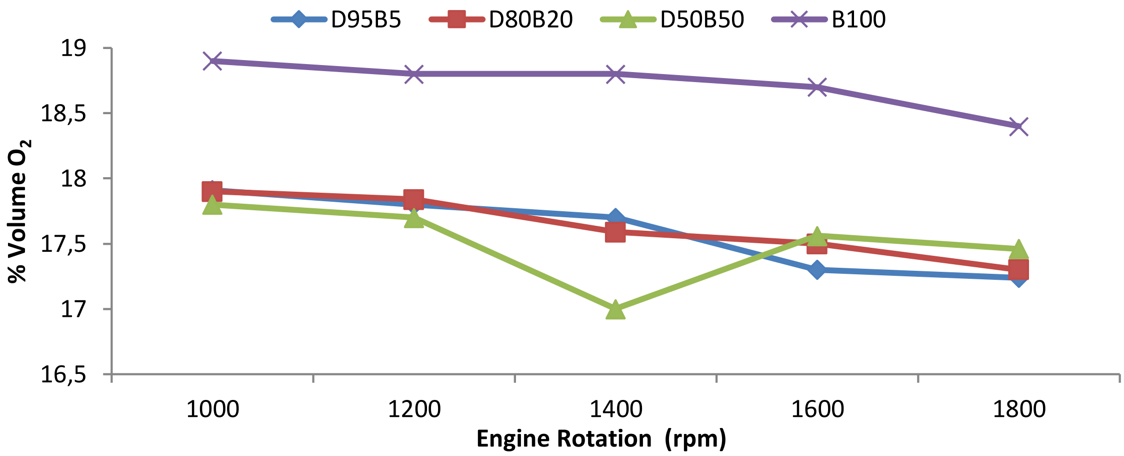


*Fig. 6. Emissions of $O_2$ in mixtures of Biodiesel.*

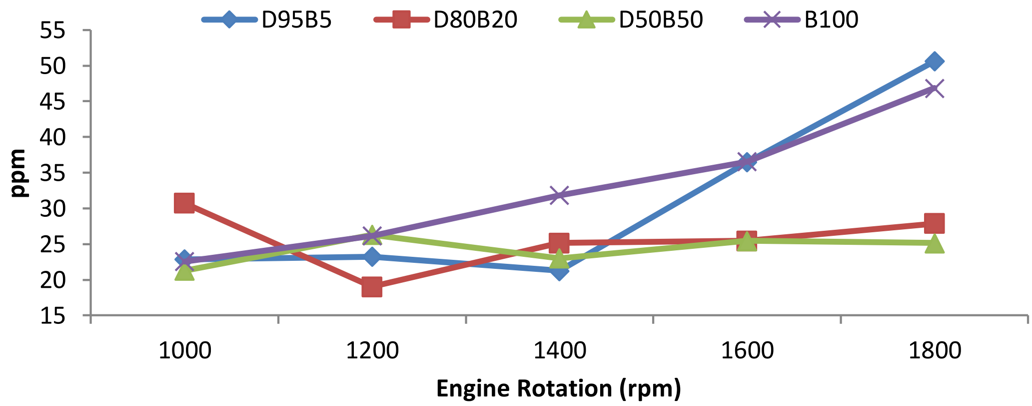


*Fig. 7. Emissions of HC in mixtures of Biodiesel.*

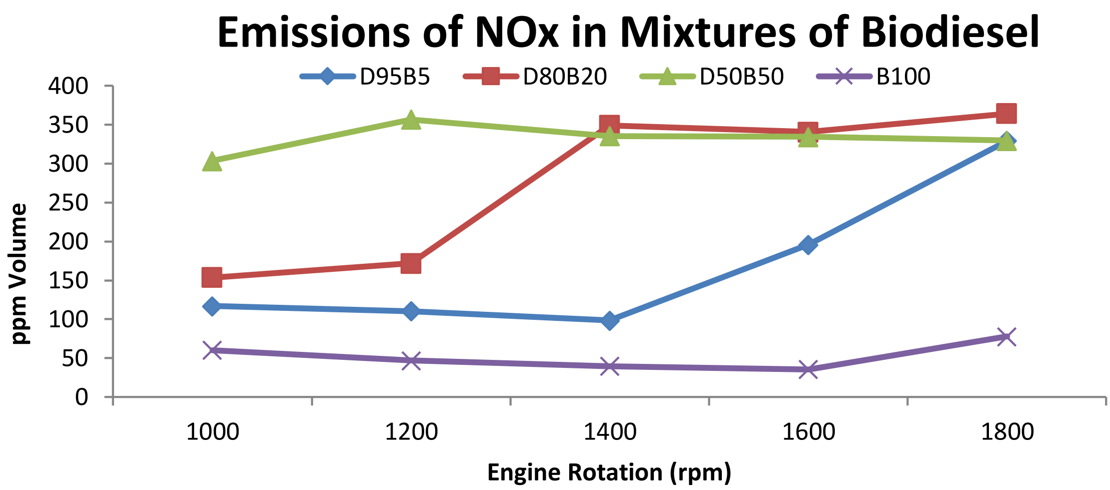


*Fig. 8. Emissions of NOx in mixtures of Biodiesel.*

NOx values B100 are inferior to other mixtures (see Fig. 8).

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