

INFLUENCE OF THE VARIATION OF THE INJECTION POINT IN THE PERFORMANCE OF A DIESEL ENGINE

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Abstract. Diesel engines, currently in operation in the Amazon region, were developed to operate at atmospheric conditions different from those found in the Amazon region, and for fuels different from those currently offered in Brazil. It is therefore necessary to modify the operating conditions and possibly some constructive parameters to lower the current specific fuel consumption. The internal combustion engines with compression ignition have gone through many technological advances aimed at improving their efficiency, reducing consumption and reducing environmental impacts. These machines currently have an electronic control system composed of sensors and actuators, which control the performance in real time according to the working condition. All these advances were made in two different ways: experimental methods or computer simulation. The experimental methods are more accurate, however they have high costs. Computational simulation has a lower cost and works with several parameters simultaneously. This implies a more comprehensive view of the general behavior of the system and produces a starting point and arrival for the experiments, reducing the costs of the project. This work aims at the numerical simulation of the combustion process in the laboratory engine and the comparison of the results with the experiments obtained in this engine, operating with diesel. Then, changes in operating conditions will be simulated in order to reduce the specific fuel consumption and identify a new point of operation of the engine.

Keywords: Diesel engine, Simulation, Specific fuel consumption.

1. INTRODUCTION

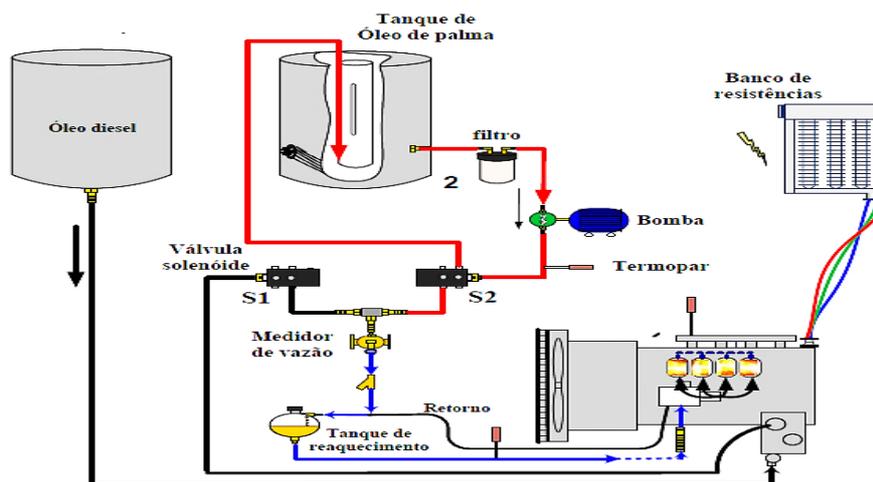
Internal combustion engines are thermal machines that convert the energy released into the fuel combustion into mechanical energy. When it comes to diesel cycle engines, the piston only compresses air until it reaches a sufficiently high temperature. When the piston approaches the top dead center, the fuel is injected spontaneously with the oxygen present in the hot air without needing a spark [5]. Compression ignition engines in operation in the Amazon region today are designed to operate in different atmospheric conditions of regional conditions (especially humidity and temperature) and different fuel currently offered in Brazil, since the current fuels have lower calorific value than those adopted in the development of the engines. These engines are designed to run on pure diesel, hence all operating points, such as fuel injection point, fuel injection pressure, duration of injection, charge, spin, cooling flow, among others, are calibrated to have the best points of efficiency in these engines. It is then necessary to modify the operating conditions.

In compression ignition engines, one of the main factors affecting combustion is the point of fuel injection [1], and a large pressure difference is required in the injector nozzle to atomize the liquid fuel into small droplets in order to allow rapid vaporization and penetration into the mass of air contained in the cylinder [2]. This work aims to analyze the combustion process through a numerical simulation, using a laboratory engine and commercial software AVL BOOST comparing the numerical results with experimental data in a previous work. After, changes in the operating conditions will be simulated in order to reduce the specific consumption and identify a new point of operation of the engine, which allows the fuel to burn faster, consequently increasing the power and reducing the consumption. For this the fuel injection point was changed. The parameters IMEP (Effective mean pressure indicated), effective power, exhaust gas temperature, ignition delay and specific consumption will be analyzed.

2. COMPUTATIONAL PROCEDURE

The simulation has four steps: the assembly of the computational model, verification, calibration and validation of the model. The assembly of the model consisted of obtaining motor data and insertion into the program. Verification and calibration consisted of comparing the results with the actual model and changing parameters to refine the model. The validation was the proof that the computational model represented a real model with the smallest possible error.

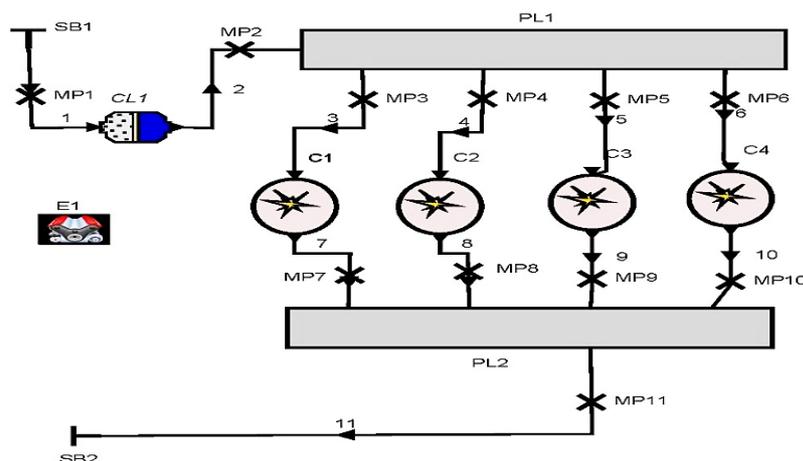
The modeling of this work using AVL BOOST software was done for the Hyundai D4BB-G1 generator set. This engine has been adapted for the use of alternative fuels like vegetable oil "in natura". The diagram below of figure 1 shows the experimental apparatus that was used.



Source: [3]

Figure 1. Experimental apparatus diagram

The AVL BOOST software offers all the components that make up a engine, like cylinders, manifolds, filters, compressors, turbochargers, catalysts and others. The model was made in a simple way and consists of four cylinders, an intake manifold and an exhaust manifold, two system boundaries, 11 measuring points and an air filter. As can be seen in figure 2.



Source: [4]

Figure 2. Model in AVL Boost

All elements present on the model have a series of input data according to its function. As the Figure 2 shows, the engine is represented by E1, the system boundaries (SB) are the elements that define the air conditions entering in the cylinder such as: pressure, temperature, fuel air ratio, combustion products and fuel vapor, the cylinders are represented by C_i , where parameters such as stroke, diameter, compression ratio, connecting rod length, etc, are entered. Lastly, it is defined the combustion model. Each model has its objective and data, as mass of fuel per cycle, start of injection, duration of combustion, delay of ignition, parameters of the chosen models, temperatures and initial pressure, rate of fuel injection,

and others, to be entered. The inlet and exhaust manifolds are represented by PL1 and PL2. In this item are inserted data referring to the volume and coefficient of flow. The measurement points (Mpi) are placed in the tubes to measure temperature and pressure.

The model was simulated with 80% and 100% of the load. It was verified and calibrated. The validation aims to secure that the model and all of the assumptions made are reasonable and well implanted, so they can show a behavior close to the real system and be able to produce similar results as well. The tables 1 and 2 were then compared to the computational model and the real model. It was verified that the error was less than 5%, which is within the uncertainties by measuring instruments.

Table 1. Comparison of results at 100% load.

100% load			
Parameters	Simulation	Real	Error (%)
Power (kW)	15,6	15,07	3,4
Specific fuel consumption (g/kWh)	290,9	281,3	3,4
Gas temperature °C	299,6	296,5	1

Source: The authors

In order to prove the validation of the simulation results, the computational model must behave as the real model. Therefore, if it is only changed the equivalent fuel quantity of the real engine, running at 80% of the load, the results obtained in the simulation should be similar to the real one obtained in the same condition. The data shown in Table 2 demonstrates that compared to the real system, it presented an error of less than 5%.

Table 2. Comparison of results at 80% load.

80% load			
Parameters	Simulation	Real	Error (%)
Power (kW)	12,6	12,3	2,3
Specific fuel consumption (g/kWh)	307,5	321,5	4,3
Gas temperature °C	267,2	259,5	2,9

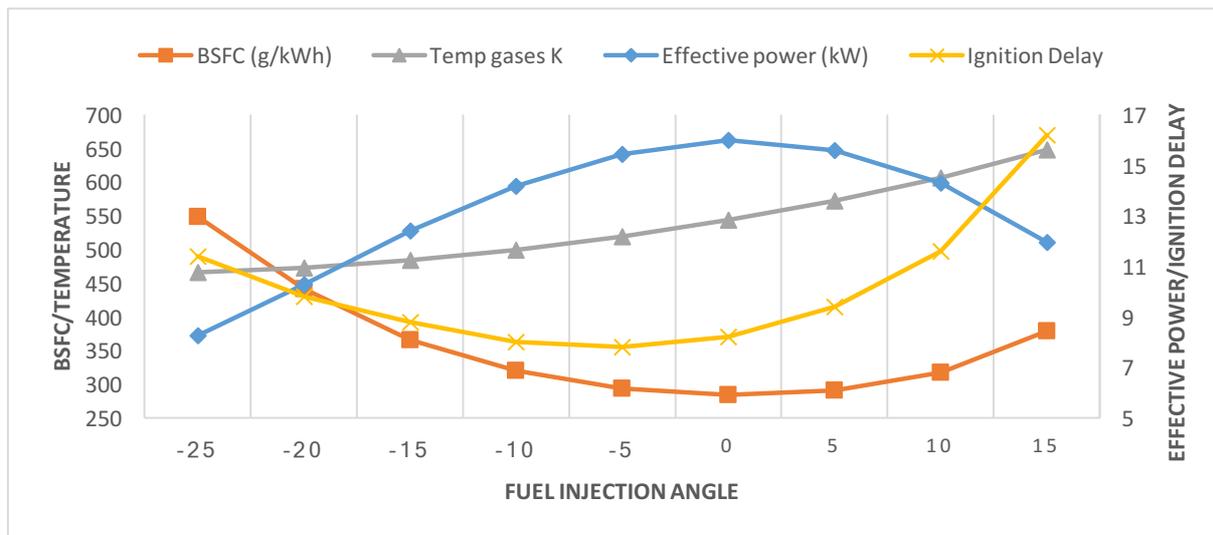
Source: The authors

As the model represented the real system well, presenting behavior and data with errors within the range of the measuring instruments, it can be affirmed that the simulation is validated.

3. RESULTS AND DISCUSSION

The injection advance influences on temperature and cylinder pressure, effective power, specific fuel consumption (BSFC) and ignition delay. Thus, this topic shows what happens to the engine operating parameters when the starting injection angle of the fuel is moved forward or backward. The parameters air flow, fuel type, rotation and load were kept constant, so the results below are influenced only by the variation of the fuel injection.

Figure 3 shows an overview with the curves BSFC, exhaust gas temperature, ignition delay and effective power in relation to the variation of the angle of injection start. By analyzing the graph above it can be noted that in the range between 5 ° and -5 ° of the fuel injection angle, the engine has a higher efficiency, showing a lower specific consumption, lower exhaust temperature and higher power. In this range of the fuel injection angle, the engine has a lower ignition delay because the fuel injected into the combustion chamber finds better conditions of temperature and pressure and turbulence in the cylinder. As a result, the combustion occurs earlier and the energy released in the combustion is used to generate positive work by reducing the losses to the exhaust.



Source: The authors

Figure 3. BSFC curves, exhaust gas temperature, ignition delay and effective power in relation to fuel injection angle.

In the range of 5° to 0° the gas temperature decreases along with the increase in power, causing a greater thermal efficiency, since the same energy of the fuel is being used to generate more power. As the increase of the injection advance continues, the temperature drops. On the other hand, delaying the fuel injection after 5° from the top dead center, the exhaust gas temperature increases due to the greater amount of the combustion energy, that is directed to increase the temperature of the exhaust gases. Thus, it means the engine is getting less efficient.

In a normal operation of the engine, the start of fuel injection occurs at 5° after the top dead center. It is noticed that the power increases due to the high pressure inside the cylinder with the increase of injection advance up to 0° . Analyzing the graph, it is also observed that with the increase of the injection advance or delay, the power decreases with exception of the range between 5° to 0° , where the power begins to fall, reaching small values after -10° and with the increase of the delay up to 5° , due to the drop in pressure inside the cylinder.

About the brake specific fuel consumption (BSFC), the specific consumption represents the mass consumption of fuel per unit of power. It is one of the efficiency factors of the engine using a certain fuel. We can notice from the analysis of the specific consumption curve that with the decrease of the injection delay the consumption falls until 0° of the fuel injection angle, and from that point on it starts to increase again. It presents a minimum between -5° and 5° . It is realized that by advancing the start of fuel injection it is possible improve the efficiency of the engine. Finally, when it comes to the ignition delay, by analyzing the graph it can be noticed that with the increase of angle of the advance or delay of fuel injection, the delay of ignition increases.

4. CONCLUSIONS

By the end of this work and according to the intended objectives, it was concluded that the fuel injection advance is a viable alternative to reduce the specific consumption and increase the efficiency of diesel engines. The simulation represented very well the actual operation of diesel engines, since the ignition delay is around 3° to 10° of the crankshaft and in the simulation for fuel injection occurring at 5° DPMS, the ignition delay is around 9° .

The injection advance affects the ignition delay of the fuel, resulting in a change in the parameters of IMEP, effective power, specific consumption and exhaust gas temperature. Analyzing the effective power it is noticed that range between 5° and -5° of the fuel injection angle, the engine has a higher efficiency, showing a lower specific consumption, lower exhaust temperature and higher power. Increase of fuel injection advance to 0° the gases' temperature has a drop with the this decrease is approximately 5%, increasing the power due to the increase in thermal efficiency of the engine.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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