17th Brazilian Congress of Thermal Sciences and Engineering
November 25th-28th, 2018, Águas de Lindóia, SP, Brazil

ENCIT-2018-0754
METHODOLOGIES FOR MEASURING SPECIFIC CONSUMPTION FUE IN COMPRESSION IGNITION ENGINES

Luany Karolynne David Braga
Antonilson Oliveira da Conceição
Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, Belém - PA, 66075-110
luany_karolynne@hotmail.com
em.antonilson@gmail.com

Hendrick Maxil Zarate Rocha
Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, Belém - PA, 66075-110
hendrick@ufpa.br

Danielle Regina da Silva Guerra
Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, Belém - PA, 66075-110
daguerra@ufpa.br

Manoel Fernandes Martins Nogueira
Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, Belém - PA, 66075-110
mfmn@ufpa.br

Abstract. *This work aims to analyze experimentally the methodologies to obtain specific fuel consumption (kg / kW.h), a singular parameter in the analysis of the economic feasibility of groups generating the diesel cycle. The specific consumption depends on the fuel consumption, which can be found through the mass or volumetric flow, and the electric power produced by the generator set. In the present work, a generator set of the brand YANMAR 4TNV88-GGE of nominal power of 21.6 kW consuming diesel oil S500, denominated of B0. The methodology used will be the simultaneous measurement of the fuel consumption using the (volumetric) and temperature-corrected volumetric (flowmeter and thermocouple), the purpose is to determine possible disparities in measurements, reflecting the achievement of specific consumption more efficiently. The experimental results obtained so far show that obtaining the specific consumption through mass flow is more efficient than the volumetric flow because the perturbations in the fuel line interfere directly in the calculation of the volumetric flow; the minimum temperature interference in the calculation of the mass flow was also another determining factor to characterize this method as the most effective.*

Keywords: *specific consumption, mass flow, volumetric flow, diesel engine*

1. INTRODUCTION

The generation of electric power from thermoelectric plants in Brazil according to the Generation Information Bank (BIG, 2017), represents 26.62% of the national percentage produced, see Fig. 1. Most thermoelectric plants use (diesel engine), which coupled to an electric motor, form the set generator set, which is responsible for the generation of electric energy. In this context, the evaluation of the efficiency in the generation of energy is crucial for the maintenance of the thermoelectric plants in operation, since most of them depend on government subsidies to operate and are supervised by government agencies (ANEEL).

Therefore a detailed study of the generator set was necessary to evaluate its efficiency and the main parameter of the analysis is the specific fuel consumption, according to Conceição (2015), the specific fuel consumption is a crucial parameter in the choice of generator sets, representing directly the cost for the operation of generating unit, which is reflected in the electricity bills.

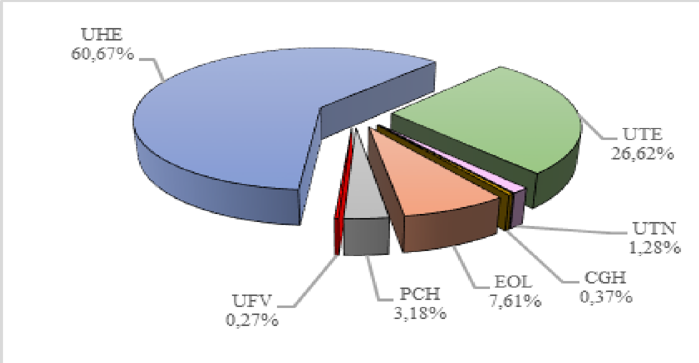

Figure 1. Percentage of energy production in Brazil in 2017 (CGH-Hydroelectric Power Plant, CGU-Central Generator Undi-electric, EOL-Central Wind Generator, PCH-Small Hydroelectric Plant, UFV-Central Solar Photovoltaic Generator, UHE-Hydroelectric Power Plant, UTE-Thermoelectric Plant, UTN-Thermonuclear Plant).
Source: BIG, 2017.

Therefore, two methods were used to determine fuel consumption: mass flow and volumetric flow, in order to find the most efficient methodology to obtain specific fuel consumption.

2. DIESEL ENGINE

In diesel engines the ignition occurs by autoignition, at the contact of the fuel injected with the air heated by the compression caused by the piston. According to Bosch (2005) during the compression time, the intake air is compressed to between 30 and 50 bar in naturally aspirated motors, so that its temperature increases to values between 700 and up to 900 ° C. The fuel is injected into the chamber slightly before the desired combustion time when the plunger is near the end of the PMS (Upper Dead-end) compression stroke. The liquid fuel is injected at high speed into the combustion chamber in several jets through the small orifices of the injector and is then vaporized as it mixes with the air at high temperature and high pressure. Since the temperature and air pressure are above the point of ignition of the fuel, it will combust after a few seconds. The time between the initial injection time and the start time of combustion is known as delay of ignition or delay of combustion. Figure 2 shows the combustion process in a direct injection diesel engine at the exact moment the piston reaches the PMS where it occurs to the injection of fuel at high pressure resulting in the spontaneous ignition, typical of diesel engines.

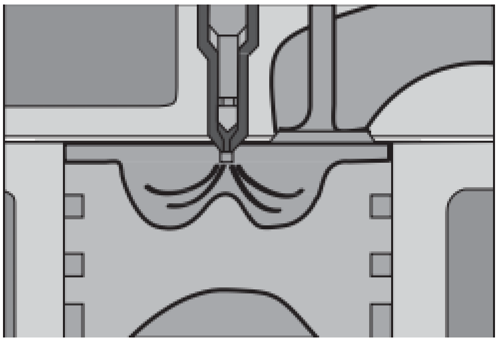

Figure 2. Combustion in diesel engine of direct injection, moment of fuel injection at the end of compression (autoignition).
Source: Brunetti, 2012.

2.1 Fuel Injection

The correct injection of fuel in the diesel engines is of paramount importance, since because of this process a heterogeneous mixture; this occurs at the edges of the spray jet through a diffusion flame the combustion mixture, which will react chemically to start combustion.

After the injection of the fuel some phenomena occur, among them the cooling of the air until the beginning of the combustion occurs, all due to the elevation of temperature and consequently vaporization of droplets of injected fuel that came in contact with the air that is in high temperature. However, if the temperature of the mixture is not high enough, the autoignition process - which occurs when temperatures are high enough to cause the fragmentation of the fuel molecules without the need for another external ignition - does not happen, making it difficult to intensification of the combustion process of the type of fuel injected. Due to the diesel oil commonly used in the diesel engine, it is more viscous - because in the formulation of the same there are high levels of sulfur, nitrogen compounds, high percentage of compounds with double bond, which at the end of the combustion process favor the formation of residues harmful to the engine and the environment, see Fig. 3, - self-ignition would be of great help.

Figure 3. Carbonized injector nozzle due to the use of S500 oil with high sulfur content.
Source: Own authorship.

However, when the temperature is raised, the change in viscosity occurs and this implies the change of the specific mass, resulting in very few results at the moment of performing the volumetric measurement calculations. Other problems may arise from this, as Cardoso (2016) explained as an over-effort in the injection pump, clogging or malfunctioning in the injector nozzles, or even, could result in increases in temperature in the combustion chamber, corroborating for the appearance of a phenomenon of carbonization.

2.2 Specific fuel consumption

In technical terms, the specific consumption, according to Brunetti (2012) is defined by the relation between the mass flow of fuel consumed by the diesel engine and the electric power produced by the generating unit, see Eq. (1).

$$CoEs = \frac{\dot{m}_{comb}}{P_e} \ (kg/kW.h) \tag{1}$$

The variables for the calculation of the specific consumption are found experimentally, where it is necessary the instrumentation of the generator group using fuel consumption meters (mass or volumetric), and electrical data (voltage, current and electric power).

The main problem is related to the measurement of fuel consumption, because in diesel engines the measurement takes place by quantifying the fuel consumption in unit time per unit mass (ex: kg/h), being that this is not obtained directly, because it depends on the methodology adopted, for example, if a flowmeter is used, it is necessary to measure the fuel flow (ex: l/ h) and transform it into mass unit with the of the specific mass (ex: m^3/kg), which varies according to the fuel temperature. Such factors can easily be manipulated improperly at the time of unit transformation, which impairs their veracity.

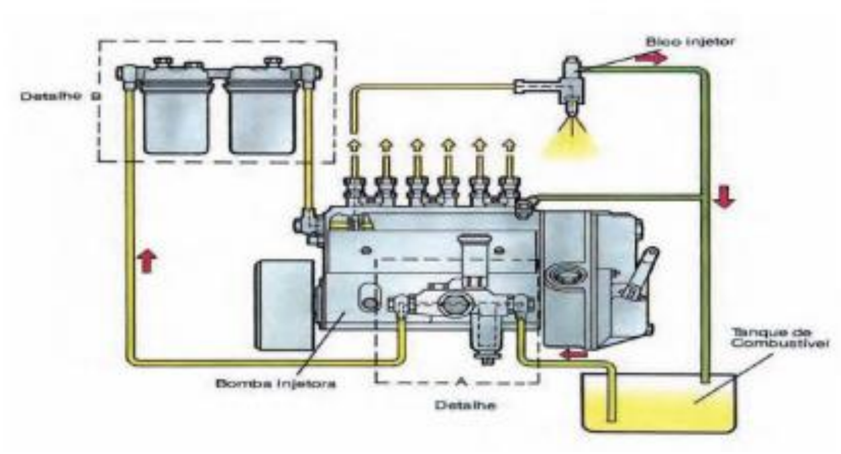

Figure 4. Diesel engine mechanical fuel injection system with in-line injection pump.
Source: MAHLE, Lightweight Motors Internal Combustion Engines Course, 2016.

Another determining factor is the influence that volumetric injection pumps have on diesel engines, see Fig.4, because due to the fact that the injection system is intermittent and alternating, these pumps cause pulsations in the fluid which often causes a change in the flow direction of the fuel, thereby increasing its frequency. This variation, depending on the scale adopted and the method chosen for measuring fuel consumption, directly influences an erroneous measurement or with little precision. In this way, the value of the specific mass in temperature, making the correct corrections for the specific consumption calculations.

3. EXPERIMENTAL PROCEDURE

The experimental procedure is presented in Fig. 5, according to Rocha (2009), where the necessary equipment for the simultaneous measurement of mass and volumetric flow of fuel and electric power are listed. In point 1, we find the balance of the brand DIGIMED, with a precision of 0.001g, with a fuel tank of 15l, which supplies the whole line with diesel S500 and feeds the diesel engine. The balance has an acquisition system that makes it possible to record the reduction in mass of fuel as a function of time, so in point 1 the mass flow of fuel is obtained. Next, in point 2, a fuel filter was installed to reduce the presence of particles and not to obstruct the flowmeter.

Point 3 presents the OVAL flowmeter, model LSF-41, with an operating range of 0.5 to 50 l and an accuracy of 1%, at which point the volumetric flow rate of fuel is obtained, which must be corrected according to the After the flowmeter is installed, a thermistor type PT100 is installed at point 5 after the flow meter, with a measurement range of -80 ° C to 260 ° C with a precision of 0.1 ° C, which is responsible for recording the temperature variation of the fuel such as the recirculation of the fuel in the injection pump, point 6, the elevation in the temperature of this which entails in the change of the specific mass that must be corrected.

Measurement of volumetric fuel flow requires that the flowmeter be immune to the disturbances generated by the injection pump, since at each injection of fuel a sudden change of pressure in the fuel supply line causes disturbances and errors of reading in the fuel line. flow meter, the solution is the installation of an expansion tank, point 4, where a pressurized tank with air attenuates disturbances in the line, keeping the flow meter immune.

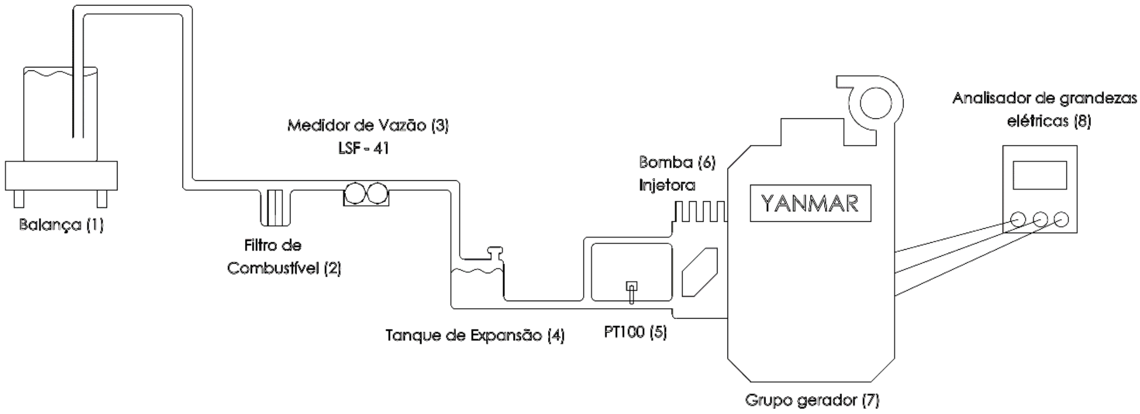

Figure 5. Experimental apparatus for measuring specific fuel consumption of a diesel generator set.
Source: Own authorship.

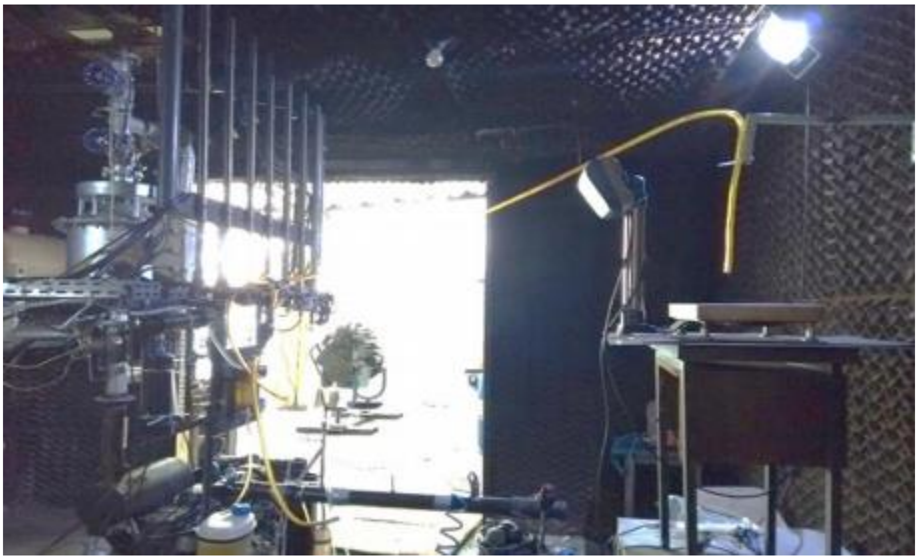

Figure 6. Experimental apparatus mounted on the Labmotor to obtain the specific consumption using different methodologies.
Source: Own authorship.

The generator set is located at point 7, it is a YANMAR model 4TNV88-GGE engine, with a nominal power of 21.6 kW, in the rotation of 1800 rpm. It is a 4 stroke diesel engine with natural suction system and of mechanical injection of fuel by rotary pump. The power produced in a generator set is the electric power, which is dissipated in a resistor bank, which simulates the loads in the generator set, the loads used in the experiment were 50, 70 and 100% of the nominal power of the diesel engine.

The electrical quantities are obtained from the SAGA 4500 equipment, installed in the generator where they are acquired: voltage, current per phase calculating the electric power produced.

In each of the loads the values obtained with the mass and volume flow were compared for the measurement of the fuel consumption for the same electric power produced. Figure 6 shows the experimental apparatus assembled in Labmotor to obtain the specific consumption using the two methodologies: flow and mass measurement.

4. RESULTS

The measurements performed in the generator set are presented in the figures, according to the standard NBR ISO 1585 (1996). The Figure 7 is a graph showing all the measured values of the mass and volumetric flow of fuel, in this graph it is possible to notice the increase of the fuel consumption with the increase of the load, in both methodologies the behavior was similar, however in the mass flow measurement does not interfere with the temperature, that is, it is obtained by the decrease of the mass deposited on the balance and independent of the variation of the specific mass of the fuel, this methodology presents a greater practicality in the obtaining and treatment of the data.

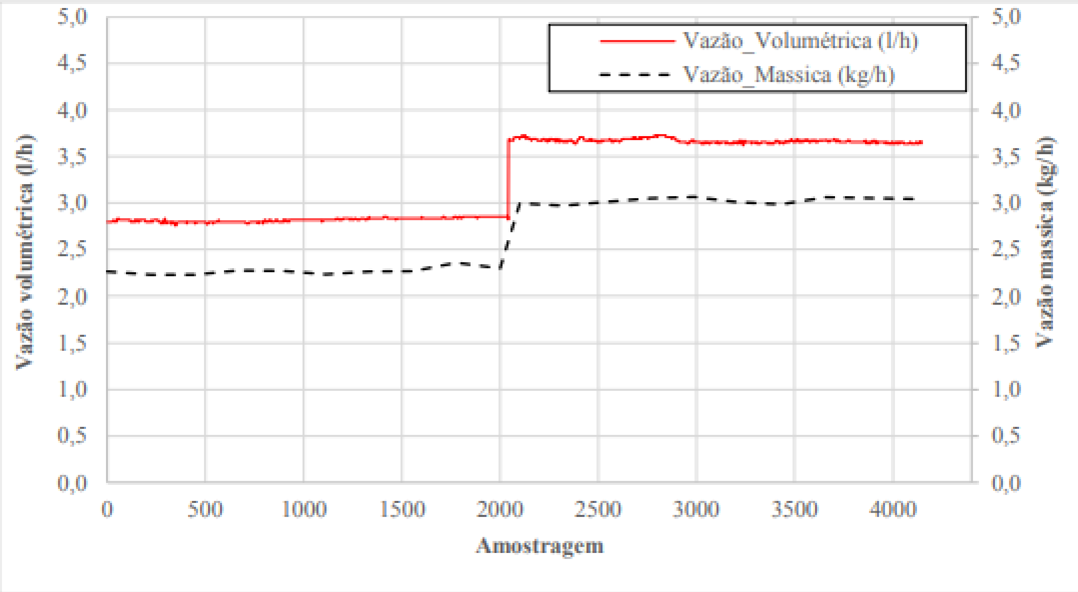

Figure 7. Fuel consumption measurement.

In obtaining the volumetric flow it is necessary to correct the value of the specific mass as a function of the temperature of the fuel, Fig. 8 shows an adjustment curve obtained experimentally, where an equation is expressed that relates the specific mass to the temperature.

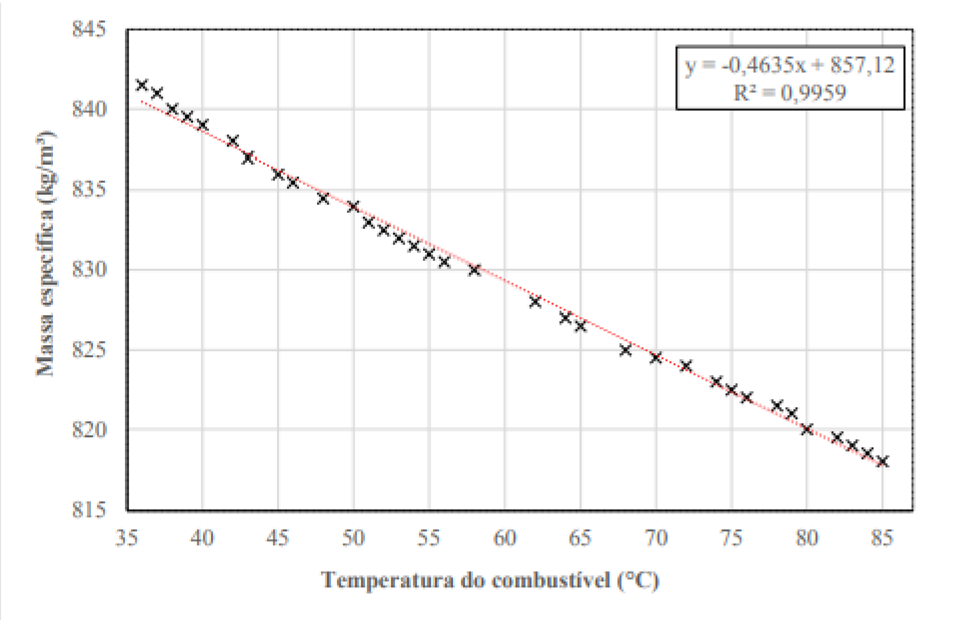

Figure 8. Variation of specific mass as a function of temperature.

The work of Park (2015) shows similar results in relation to the specific mass of fuel, in his experiments, he obtained the same graph showing the decay of the specific mass as a function of the elevation of the fuel temperature, which validates the corrections that must be measurement of the volumetric flow rate for obtaining the mass flow rate.

The specific fuel consumption obtained from the two methodologies of flow measurement (mass and volumetric), is presented in Fig. 9, with the increase of the load in the generator set, the reduction of its specific consumption, in this way, this generator set presents higher thermal efficiency at 70% load, in both cases. There is also a small disparity in the values presented around 1%, this shows that both methodologies are effective in measuring specific fuel consumption, however, we must take into account that the value found with the mass measurement does not need be corrected, which must be carried out with precision in the volumetric flow rate.

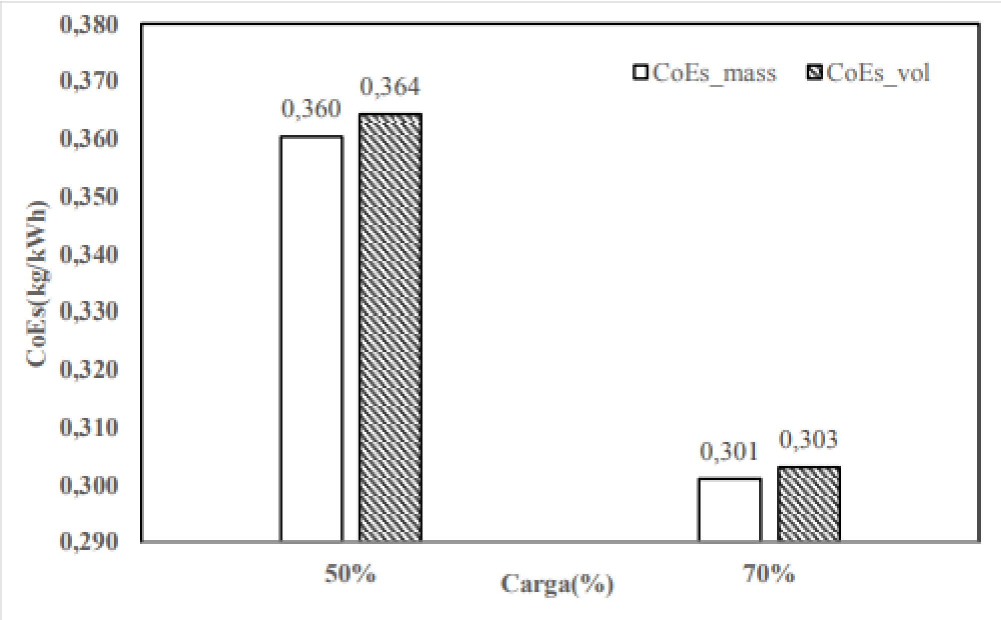

Figure 9. Specific fuel consumption as a function of load.

5. ACKNOWLEDGMENTS

This work was possible with the support of the Motors Laboratory of the Federal University of Pará and, in particular, the master's degree Antonilson Oliveira and the professor Dr. Hendrick Zarate.

6. REFERENCES

Associação Brasileira de Normas Técnicas. Norma NBR ISO 1585; “Veículos Rodoviários - Código de ensaio de motores - Potência líquida efetiva”. Junho de 1996.

Bosch, Robert. “Manual de Tecnologia Automotiva”, tradução Helga Madjderey, Gunter W. Prokesch, Euryale de Jesus Zerbini, Suely Pfeferman – São Paulo: Edgard Blucher, 2005.

Brunetti, Franco. “Motores de Combustão Interna: volume 1”. São Paulo: Blucher, 2012.

Cardoso, Andrew Cantanhêde. “Caracterização de spray de mistura ternária diesel-etanol-óleo vegetal”. Dissertação (graduação em engenharia mecânica) - Faculdade de tecnologia, departamento de engenharia mecânica, Universidade de Brasília, Brasília, 2016.

Conceição, Antonilson Oliveira da. “Consumo Específico. In:______.Recuperação e Comissionamento De Um Grupo Gerador Modelo Yanmar – 4tnv88 – Gge De 20 Kva Com Motor Diesel”. Belém: 2015, pg 42.

Mahle, Curso Metal Leve Motores de Combustão Interna, Manual Técnico, 2016.

Rocha, Hendrick Maxil Zárate. “Aparato e Metodologia Experimental. In: _____.Combustão de Óleos Lubrificantes Usados em Motores Diesel”. Belém: 2009, pg 33.

Park, Youngsoo. “Effects of diesel fuel temperature on fuel flow and spray characteristics”. Republic of Korea 2015, pag 4.

7. RESPONSIBILITY NOTICE

The author(s) is (are) the only responsible for the printed material included in this paper.