

CONVERSION OF TURBOCHARGED DIESEL ENGINE TO OPERATE SOLELY WITH HYDROUS ETHANOL

B. L. C. Queiroga^a,
E. F. Jaguaribe^b,
M. S. J. Gonçalves^c,
B. L. N. Oliveira^d,
and A. S. Rumão^e

^a Universidade Federal do Pará
Departamento de Engenharia de Energias
Renováveis
Jardim Cidade Universitária
CP. 58059-900, João Pessoa, Paraíba, Brasil
bruno_queiroga@ufpi.edu.br

^{b,c,d,e} Universidade Federal do Pará
Departamento de Engenharia Mecânica
Jardim Cidade Universitária
CP. 58059-900, J. Pessoa, Paraíba, Brasil.

Received: December 9, 2012

Revised: January 04, 2013

Accepted: January 29, 2013

ABSTRACT

This paper discusses the conversion of a turbocharged diesel engine to operate with hydrous ethanol, using procedures developed in Innovation Lab of UFPB, IL. An diesel engine, brand Perkins, model 1104C-44TAG2, was converted to operate with hydrous ethanol at the time that it amended its compression ratio of 18:1 to 9.3:1, suitable for an Otto Cycle engine to non-occurrence of detonation fuel. Comparing experimental data generated for the converted engine tests (which ranged the ignition advance, stoichiometric air/fuel ratio and rotation at 1800 rpm) with those obtained in tests with the original engine, and converted, 45 kWe, a cost reduction of 34 % with Ignition Advance of 20°. It was taken into account in this analysis, and data on fuel consumption, the cost of diesel, R\$ 1.90/liter, and hydrous ethanol, R\$ 0.70/liter. Regarding the gaseous emissions, depending on the load, it was found that the NO_x ranged from 50 to 1050 ppm, CO, 1 to 3 %, CO₂, 12 to 15 % and HC 150 to 450 ppm.

Keywords: Diesel, Hydrous Ethanol, Turbocharger, Conversion Diesel Cycle to Otto Cycle, Gaseous Emissions.

INTRODUCTION

Brazilian sugar-alcohol industries are notable by intensive use of diesel engines that serve generators, irrigation pumps, fleets of trucks and tractors. A survey in São Paulo, Brazil, showed that 55 % of this state's rural irrigation is performed with diesel engines (Frizzone and Marques, 2006). The use of diesel is expensive. For example, in 2007, it was found that a distillery midsize northeastern Brazil has spent around R\$ 1,700,000.00 to irrigate 400 ha/day. This represents about 23 % of the total diesel use in the industry, while their costs with diesel in tractors are around 28% (<<http://www.polobio.esalq.usp.br>>, 01 Apr. 2008). Due to the ease of partially replace diesel in trucks, some distilleries in southern Brazil have employed the ethanol they produce, ensuring thus reducing of the fuel costs and emissions.

Given that: the most modern diesel engines with electronic fuel injection do not allow the use of mixtures diesel-ethanol; new diesel engines have been equipped with turbo compressors, allowing an increase in its thermal efficiency (Heywood, 1988); the Innovation Lab UFPB (IL) has been perfecting the process of conversion of Diesel Cycle to Otto Cycle, for the exclusive use of natural gas (GN), liquefied petroleum gas (LPG), and hydrous ethanol (Jaguaribe et al., 2007, Rumão, 2008, Oliveira, 2009,

Ferraz, 2010 and Queiroga, 2009); it is observed that there are technical and economic feasibility of converting the new turbo diesel engines to operate on ethanol.

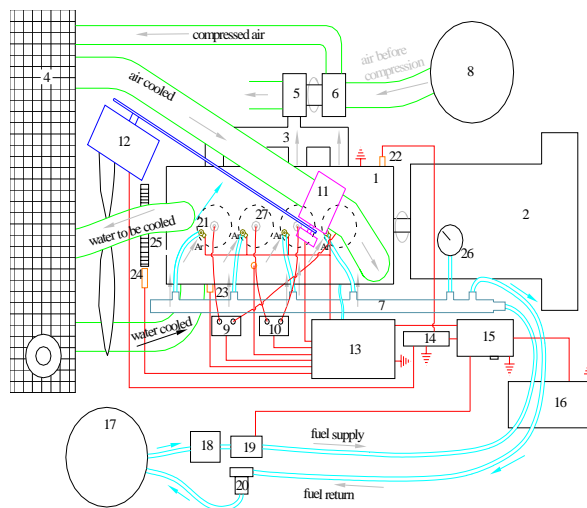
This paper discusses the process of conversion, conducted by IL, in a Perkins diesel engine, model 1104C-44TAG2, stationary, turbocharged, four cylinders, with 102 kW of continuous electrical power, to hydrous ethanol using a system programmable injection and ignition. Converted engine performance is compared with that do diesel engine, with respect at electrical power generated, at fuel consumption, at costs power generated and emissions gaseous.

METHODOLOGY

Initial tests with the diesel engine were performed for comparison with engine after conversion. In these tests, it was used an electric dynamometer, an electronic scale and a computer. Electrical powers, from 10 kWe up to maximum power (verified by the imminence of the brake), were imposed on the motor. The rotation was maintained at 1800 rpm, with the aid of an electronic regulator of velocity. In each power was observed fuel consumption.

To perform the conversion of the diesel engine,

all the components of the engine feed diesel system were replaced. Pipes, pump and nozzles of diesel were replaced for ignition coils and spark plugs (characteristic of spark ignition engines). Besides these components, were added to the engine: a electronic control unit (ECU) for control of injection and ignition of the fuel, fuel injectors, fuel rail, throttle body with TPS, phonic wheel, rotation sensor, electric fuel pump, fuel pressure regulator, fuel filter and a tank where it is stored hydrous ethanol. The compression ratio the original engine was changed from 18:1 to 9.3:1, from the modification of the cylinder head and adding spacers. The selection of components and how they were installed, as well as modifications of the cylinder head, were suitable for turbocharged engines. A schematic of the motor after conversion is shown in Fig. 1.



Legend:

1-cylinder head/intake manifold;	14-central electronic governor;
2-generator of electricity;	15-central motor starting;
3-exhaust manifold;	16-battery;
4-radiator/after cooler;	17-fuel tank;
5-turbine;	18-fuel filter;
6-compressor;	19-fuel pump;
7-fuel flute;	20-fuel pressure regulator;
8-filter air intake;	21-fuel injectors;
9-1st and 4th cylinders ignition coil;	22-speed sensor electronic governor;
10-2nd and 3rd cylinders ignition coil;	23-water temperature sensor;
11-throttle body;	24-speed sensor system injection / ignition;
12-actuator electronic governor;	25-phonic wheel;
13-UCÉ;	26-gauge fuel pressure;
	27-spark plugs.

Figure 1. Scheme engine converted after appropriate modifications to hydrous ethanol.

The tests are conducted by adjusting the engine converted for operation with stoichiometric mixtures, rotation at 1800 rpm, fuel pressure of 6 bar, varying

the Ignition Advance (IA) of 12.5° to 20° . For the evaluation of engine performance converted, beyond of the equipment used in the tests of the original engine, made up using a gas analyzer to maintain stoichiometric mixture.

RESULTS AND DISCUSSION

Figure 2 shows the data of fuel consumption as a function of electric power generated as a result of the tests with the engine originally diesel.

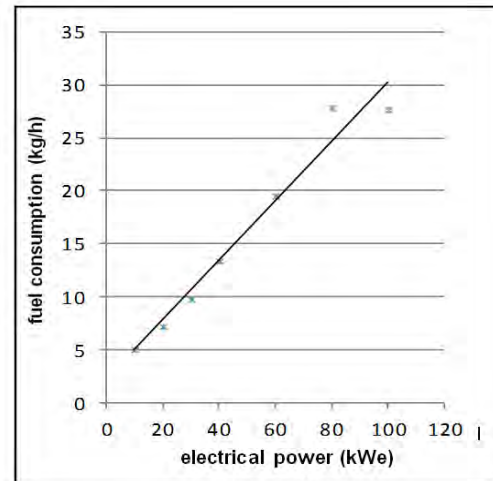


Figure 2. Fuel consumption, depending on the electric power, related to diesel.

From Fig. 2 it is observed that the engine, originally diesel, presented a fuel consumption varied from 5.07 to 27.88 kg/h, depending on the electrical power generated. The maximum power achieved was 100 kWe.

Figure 3 shows the data of fuel consumption as a function of electrical power generated as a result of the tests with the converted engine.

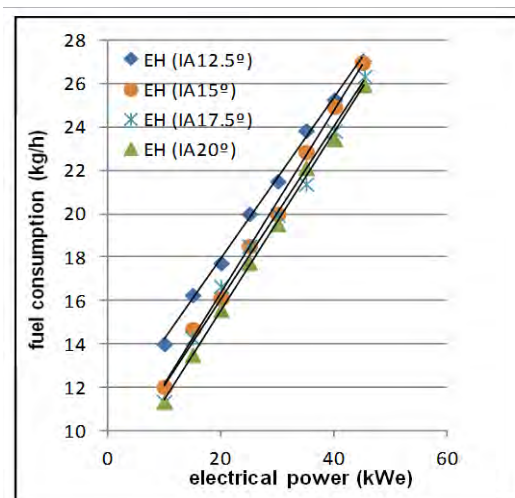


Figure 3. Fuel consumption, depending on the electrical power and IA, related to hydrous ethanol.

From Fig. 3 it can be seen that the fuel consumption tends to increase with increasing electrical power, and with the growth of the IA, fuel consumption declines. The maximum power reached, in all configurations, was at around of 45 kWe. At maximum power, the converted engine consumed 27 kg/h of fuel with IA 12.5°. Already with IA 20° it showed a consumption of 25.9 kg/h.

In turn, Fig. 5 presents cost of electrical power generated, as a function of electrical power generated, considering the curves of fuel consumption (Figures 2 and 3), density of hydrous ethanol (810.5 kg/m³) and of the diesel (842.4 kg/m³) and the diesel and hydrous ethanol's cost of the liter to plants sugar cane, R\$ 1.90 and R\$ 0.70, respectively.

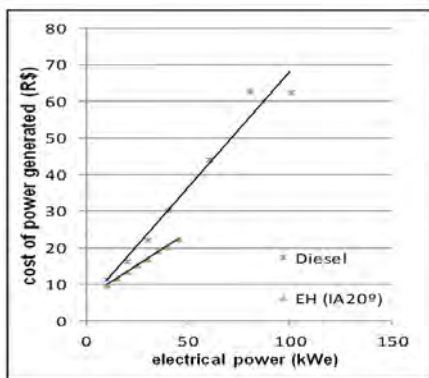


Figure 4. Graph of cost of electrical power generated by the use of hydrous ethanol and diesel, according to the electrical power generated.

According to Fig. 4, it can be seen that for all powers analyzed, the cost of power generated arising from the use of diesel remained above of generated by the use of ethanol. In particular, it was observed that the generation cost of 45 kWe has been R\$ 33.00, with use of diesel e R\$ 22.00, using ethanol.

Figures 5, 6, 7 and 8 shows the emissions of CO, CO₂, HC and NO_x observed during the experiments with the converted engine.

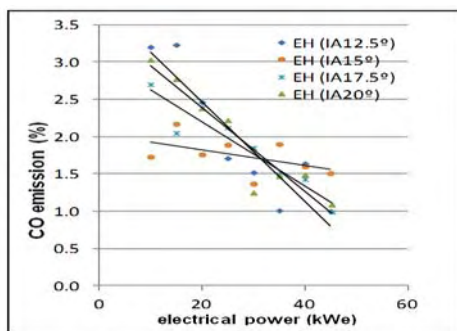


Figure 5. Graph of CO emission as a function of electrical power generated by varying the Advancement of Ignition.

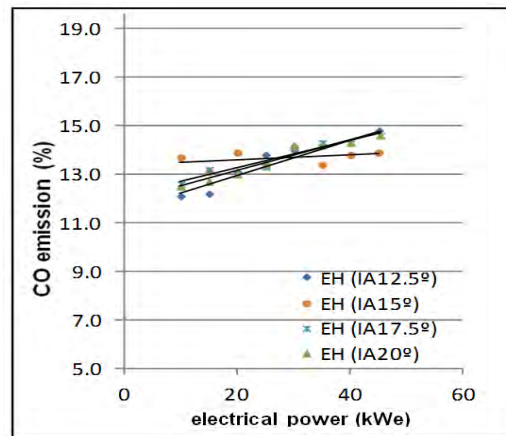


Figure 6. Graph of CO₂ emission as a function of electrical power generated by varying the IA.

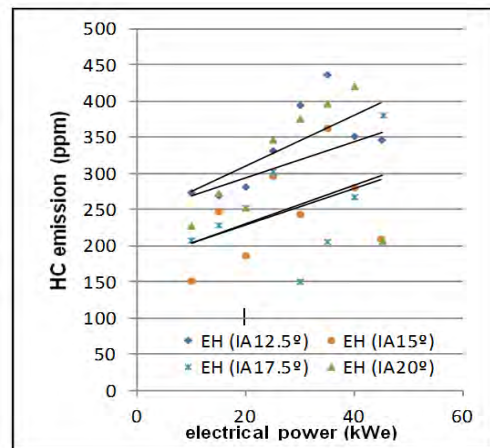


Figure 7. Graph of NO_x emission as a function of electric power generated by varying the IA.

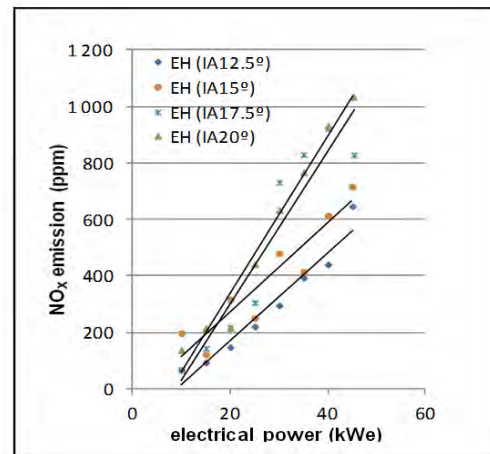


Figure 8. Graph of HC emission as a function of electric power generated by varying the IA.

The CO emission shows itself higher for greater powers, varying little with Ignition Advance. In the case of CO₂ emission, was perceived an increase with the load variation and with the ignition advance.

There was an increase in the levels of HC with the growth of electric power generated and in relation to NO_x emissions there was a considerable changing with the increase of the power.

Depending on the load and the Ignition Advanced, NO_x emissions were situated in the range of 50-1050 ppm, CO, between 1 and 3 %, CO₂, 12 to 15 %, and the HC between 150 and 450 ppm.

CONCLUSIONS

The diesel-ethanol conversion process was based on the technique developed in the IL, where few changes are made in the original motor. In the engine evaluation were employed an electric dynamometer, a gas analyzer and an electronic scale. The supply system and ignition of the air-fuel mixture responded the needs of experimental tests.

The diesel engine, in the initials tests, reached 100 kWe, observing consumptions between 5 to 28 kg/h, depending on the load applied.

In the tests with the converted engine, at 1800 rpm, CR of 9.3:1, stoichiometric mixture, was observed lower fuel consumption in IA 20 °. In this case, the maximum power generated was 45 kWe with fuel consumption of 25.9 kg/h.

The CO emission shows itself higher for greater powers, varying little with Ignition Advance. In the case of CO₂ emission, was perceived an increase with the load variation and with the ignition advance. There was an increase in the levels of HC with the growth of electric power generated and in relation to NO_x emissions there was a considerable changing with the increase of the power. Regarding the gaseous emissions, depending on the load, it was found that the NO_x ranged from 50 to 1050 ppm, CO, 1 to 3 %, CO₂, 12 to 15 % and HC 150 to 450 ppm.

Analyzing the cost of power generated by the original and converted engine, it was found savings of up to 34 % with ethanol use, power generating around 45 % of the power of the diesel engine.

REFERENCES

Ferraz, F. B., 2010, Conversão para Gás LP de um Motor Diesel com Bicos Injetores Internos à Tampa de Tuchos, Master Thesis, Universidade Federal da Paraíba, João Pessoa, PB. (*in Portuguese*)

Heywood, J., 1988, *Internal combustion engine fundamentals*, McGraw-Hill.

Jaguaribe, E. F., Rumão A. S., Oliveira, B. L. N., Queiroga, B. L. C., Ferraz, F. B., and Filho, R. M., 2007, Desempenho de um Grupo Gerador Operando com Motor Diesel Convertido para Funcionar apenas com Gás Natural, in: *8º Congresso Iberoamericano de Engenharia Mecânica*, Cusco. (*in Portuguese*)

Marques, P. A., Marques, T. A., and Frizzone, J. A., 2006, Viabilidade Econômica sob Condições de Risco para a Irrigação da Cana-de-Açúcar na Região

de Piracicaba-SP, Irriga, Botucatu, Vol. 11, No. 1, pp. 55-65. (*in Portuguese*)

Oliveira, B. L. N., 2009, Conversão de um Motor a Diesel para Operar apenas com Gás Liquefeito de Petróleo, Master Thesis, Universidade Federal da Paraíba, João Pessoa, PB. (*in Portuguese*)

Queiroga, B. L. C., 2009, Conversão de um Motor Diesel para Álcool Hidratado usando Sistema de Injeção Eletrônica Multiponto de Combustível e Ignição Estática, Master Thesis, Universidade Federal da Paraíba, João Pessoa, PB. (*in Portuguese*)

Rumão, A. S., 2008, Desempenho de um Motor Diesel Estacionário Convertido para Gás Natural em Função de sua Taxa de Compressão. Master Thesis, Universidade Federal da Paraíba, João Pessoa, PB. (*in Portuguese*)