Contribution to experimental research of alternate fuel fumigation in single cylinder research diesel engine

Doru Baldean[1,*], *Dan* Moldovanu[1], and *Adela-Ioana* Borzan[1]

[1]Tehnical University of Cluj-Napoca, Automotive and Transportation Department, 400641 Muncii Boulevard, Romania

Abstract. The advanced engineering scientific paper encompass the problem of supplying fuel in engine's combustion chamber in order to outline the influence of operating regime and fumigation method upon injection and fuel consumption. It develops a theoretical and experimental approach of the system components from Lombardini compression ignited engine test bench in relation with consumption and fumigation parameters. There was monitored engine speed, dynamic behaviour at some distinct operating loads. The opportunity for experimental research of the fumigation method in compression ignited engine resides in the state of the art technology accessible today for alternate fuel supply inside engine through this process. The results are analysed and discussed in detail. The fuel fumigation method is applicable to the presented engine and leads to some positive behaviour in operation.

1 Introduction

This paper develops a theoretical and applied research protocol which is a part of the complex phenomenological mapping of a Single Cylinder Research Diesel Engine (SCRDE), which has as result even an innovation patent with the fumigation features.

In the present age, when the expectations concerning the fuel supply systems for internal combustion engines are higher and strictly evaluated and the operation is electronically controlled it is both necessary and important to reconsider and adjust the existing knowledge and methods for air-fuel mixture formation in order to improve engine performances at economy and pollution levels.

The research paper shows a set of operating theories from the bottom of this system, a study of the fuel supply system from the internal combustion engine and a set of results from the experimental research concerning the dynamic behaviour in various operating conditions during the laboratory tests made with a hydraulic brake.

2 State of the art in the field

2.1. Review of the scientific literature

The fumigation problem is being studied and treated with serious concern by the scientific and engineering community for a time now. Bio-fuels and fumigation are two major directions that are closely considered by a specific part of the scientific research literature [1-3].

Bio-fuel has come under consideration due to the effect of fossil oil crisis. Bio-fuels are acting as a renewable replacement of petroleum fuels due to some environmental and economic benefits. Bio-fuel can be produced from different kinds of raw materials. Researchers have seen that absolute utilization of bio-fuel is not appreciable as it will affect the food chain but the blend of bio-fuel with conventional fuel could precisely reduce its use and become beneficial to greenhouse effect. It has been inferred that in the hot and cold environment bio-fuel is not fully convenient to replace fossil fuel. In the controlled environment with modified combustion equipment, biodiesel can be used as an alternate fuel 5.

Cheng et al. [1] and Zhang et al. [4,5] have described the fumigation methanol effect on different emissions of exhaust gases and particulate matter (PM) [4-11].

Intensive investigation on different alcohols, mainly ethanol and methanol and combination of them with diesel fuel is used for reducing the emissions of nitric oxides (NO_x) and PM [1]. The diesel fuel and alcohols are generally employed together either in the blended mode or even in the fumigation mode [5-9], although there are less investigation being conducted on different approaches like dual fuel injection system. In comparison to the blended mode, the fumigation method is definitely seems more flexible despite extra fuel injection system is required. First it allows the quantity of alcohol to vary at the time of injection to meet the actual demand. Second, since the alcohol is not premixed while using as diesel fuel, an emulsion additive is added to ensure proper mixing of the alcohol [4-11].

2.2 Our activities related to the subject

The research team has a constant preoccupation for developing studies and research programs for optimizing internal combustion engines and for smoothing the

* Corresponding author: doru.baldean@auto.utcluj.ro

transition toward a cleaner environment and less pollutant automotive field.

Last year, the effects of an experimental bioethanol fumigation application using an experimental ultrasound device on performance and emissions of a single cylinder Diesel engine have been experimentally investigated. Engine performance and pollutant emissions variations were considered for three different types of fuels (biodiesel, biodiesel-bioethanol blend, and biodiesel-fumigated bioethanol). Reductions in brake specific fuel consumption and NO_x pollutant emissions are correlated with the use of ultrasonic fumigation of bioethanol fuel, comparative to use of biodiesel-bioethanol blend [5, 6].

Considering the fuel consumption as Diesel engine's main performance parameter, the proposed bioethanol's fumigation method, offers the possibility to use more efficient renewable biofuels (bioethanol), with immediate effects on environmental protection [5-7].

2.3 Continuation of the study at the present moment

In the present stage there is a patent proposal in progress on a method for multi-fuel supply in the internal combustion engines with aerosols produced through ultrasonic waves applied to biofuels based on alcohols and a research concerning fumigation in the air-fuel supply system from compression ignited engine. Also the phases of development for the internal research project at Technical University from Cluj-Napoca are treated with full responsibility in order to achieve the proposed objectives.

3 Mathematical models

To study all the engine's parameters concerning the consumption, optimal operation, output power, torque and break specific consumption it is necessary to highlight the mathematical models which are at the basis of each calculation after experimental measurements.

Hourly fuel consumption is determined with the mathematical relation 8:

$$C_h = 3.6\frac{V \cdot \rho}{\tau} = 3.6\frac{m}{\tau}, \quad (1)$$

in which: V is the injected fuel volume in a given time [ml]; τ – the time in which the fuel volume V is injected, measured [s]; ρ – fuel density, in [kg/h]; m – the fuel mass in [g].

Brake specific fuel consumption is determined with the mathematical relation [8]:

$$c_e = \frac{C_h}{P_e}, \quad (2)$$

in which: C_h is the hourly fuel consumption [kg/h]; P_e – the brake mean effective power [kW].

4 Materials and method

In order to develop the research work and to measure all the envisaged parameters the engineering staff and technicians prepared a test bench with an internal combustion engine from tractor company Lombardini, that operates on the fundamental cycle of four stroke compression ignition, with a single cylinder and direct injection, being air cooled. Beside the single cylinder research engine there were also used some devices to measure the temperature, the engine speed, the output torque and power.

Figure 1 represents the schematic principle of ultrasonic fumigation process and technology [6].

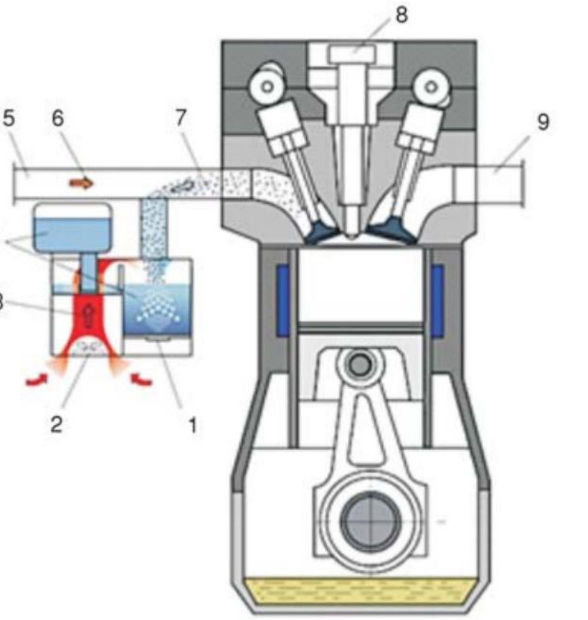

Fig. 1. Schematic principle of ultrasonic fumigation process [6] 1-ultrasonic emitter; 2-fan, 3-air; 4-bioethanol; 5-intake pipe; 6-intake pipe air stream; 7-fumigated bioethanol; 8-fuel injector; 9-exhaust pipe.

Method applied in this research uses the causal relation to highlight the influence of the innovative procedure of fumigation when supply the fuel to engine intake, using also a special procedure of sonication.

Also the methodology for determining the operating and economic parameters follows a protocol similar to the one presented in figure 2.

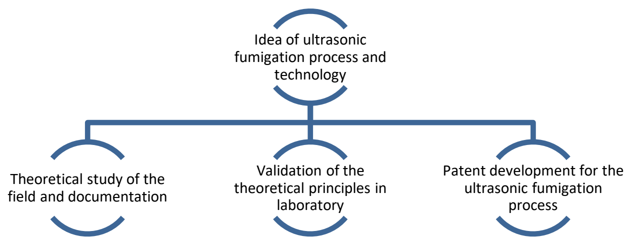

Fig. 2. Simplified methodological protocol followed in the research

5 Analyze of the experimental results

5.1. Test bench configuration

Figure 3 presents the engine test bed and the equipment linked to the bench in order to measure and determine the fuel consumption parameters.

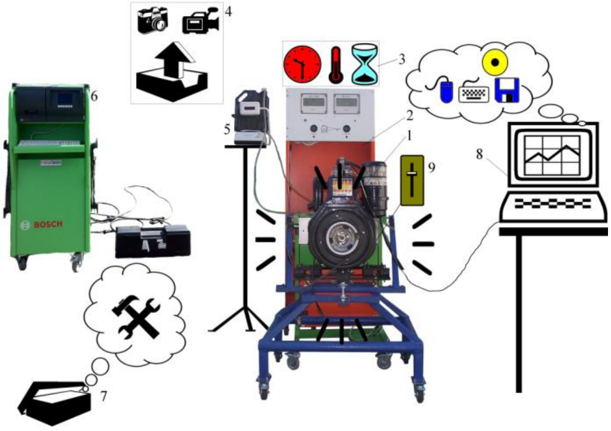

Fig. 3. Experimental test bed [3]
1-single cylinder engine; 2-hydraulic brake, 3-measuring and control devices; 4-recording equipment; 5-mass measuring equipment; 6-gas analyzer; 7-tools; 8-data acquisition system; 9-engine load adjustment lever.

Monitoring the parameters and tracing the engine operation diagrams during the tests were realized with a specialized data acquisition system, which is made of auxiliary devices and also optical units for electronic data storage. Single cylinder engine is mounted on a test bed mechanically coupled with a hydraulic brake and electronically linked with data acquisition/storage system. Also the engine exhaust pipe is connected with the gas sensor of the pollutant analyzer.

5.2. Torque and pressure measurement

In order to obtain reliable torque measurements (Table 1) the engine's crankshaft was break down by a hydraulic brake and the indicated values were recorded from a corresponding display panel (Fig. 4). The level of engine speed (Table 2) was measured with sensors put on the engine and upon hydraulic brake. In relation with the engine speeds and combustion chamber gas pressure data, the processing system has represented the indicated diagram (pressure vs. volume), thus being possible a series of complex analyzes concerning energetic performances during the operation in different fuel supply (injection, fumigation etc.) conditions.

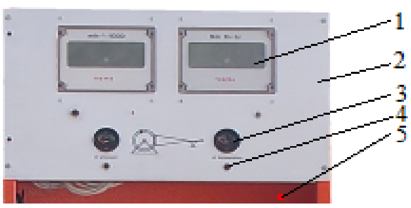

Fig. 4. Experimental data display panel
1-digital display (i.e. engine speed and torque); 2-central panel, 3-analog display; 4-conecting socket; 5-hard frame support.

Table 1. Values for Engine Torque in the case of two fuels tested at full load (100%)

Symbol	Quantity	Experimental values, [N]
M100.100%.M	Engine torque determined in the case of injecting in cylinder conventional Euro 5 diesel fuel	1.655 5.020 10.137 15.077 20.089 25.472
B20.100%.M	Engine torque in the case of 20% biodiesel volume mixture with conventional diesel fuel	1.672 5.036 10.112 15.050 20.090 25.378

Table 2. Values for Engine Speed during testing

Symbol	Quantity	Experimental values, [rot/min]
M100.100%.n	Engine speed determined in the case of injecting in cylinder conventional Euro 5 diesel fuel	2986 2911 2835 2830 2700 2510
B20.100%.n	Engine speed in the case of 20% biodiesel volume mixture with conventional diesel fuel	2978 2889 2828 2825 2698 2500

5.3. Engine load results displayed on chart

The practical determinations were presented on graphic charts in order to facilitate their observation, to describe their trends and to study engine's behavior (Fig. 5). The engine's load coefficient presents high levels when torque output riches the upper scale indicated by the manufacturer.
At low torques the engine loads are similar, but at the maximum points the load differs between the biodiesel and diesel fuel delivered to the combustion chamber.

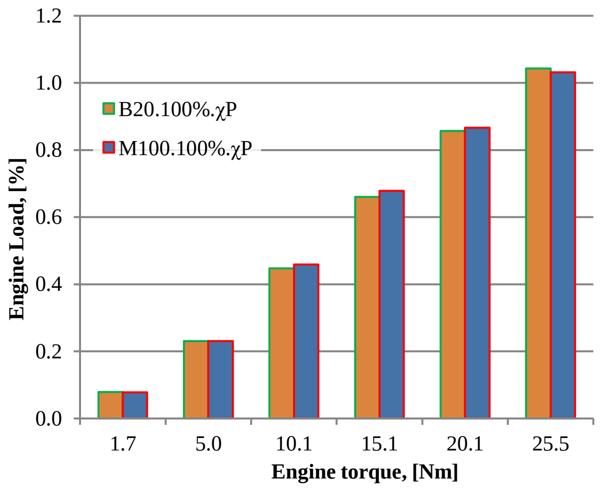

Fig. 5. Variation of engine load coefficient (χP) versus torque

5.4. Fuel consumption determination

Engine's (hourly and specific) fuel consumptions determined on test bench in laboratory conditions are represented in comparative graphics (Fig. 6 and Fig. 7).

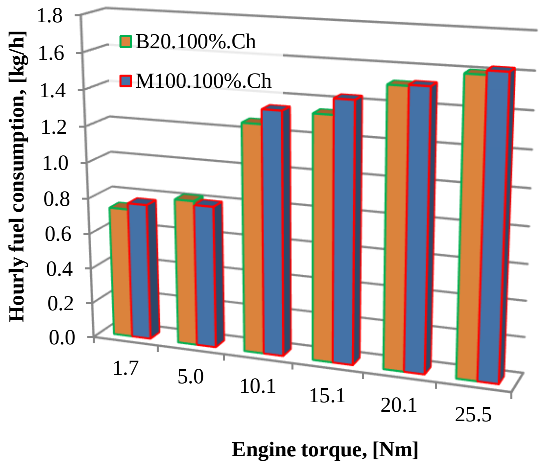

Fig. 6. Variation of hourly fuel consumption versus torque

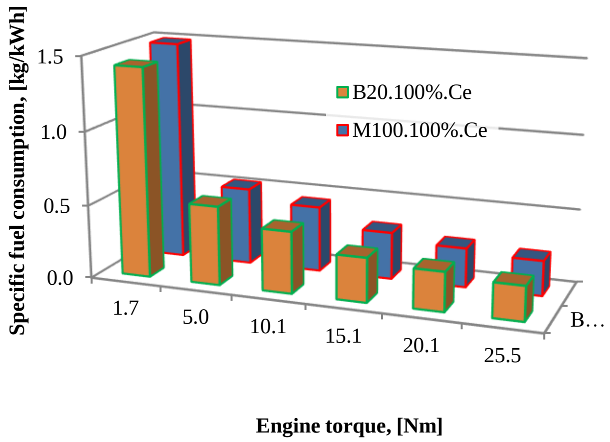

Fig. 7. Variation of specific fuel consumption versus torque

It was observed that the fuel consumption in both case of fuel delivery methods are close related to the engine's torque output.

5.5. Environment impact evaluation

In research developing process a particular phase was reserved to the environmental impact evaluation. There were recorded all the relevant data related to the smoke opacity (Fig. 8) and nitric oxides (Fig. 9).

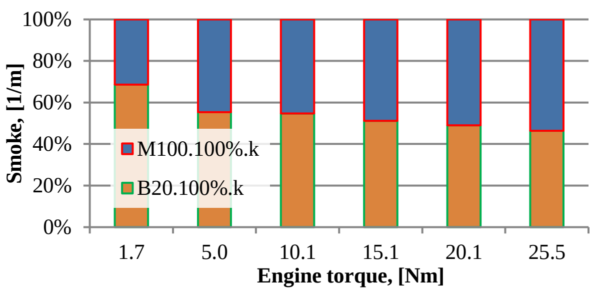

Fig. 8. Variation of exhaust smoke coefficient (k) versus torque

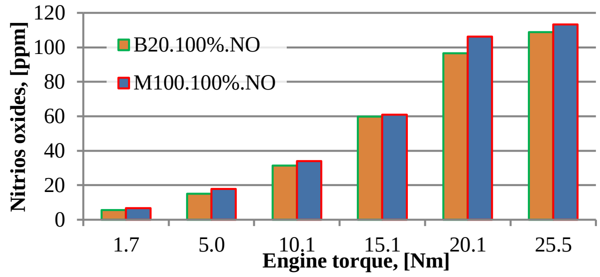

Fig. 9. Variation of nitric oxides (NO_x) versus torque

5 Conclusion

Engine's (hourly and specific) fuel consumptions determined on test bench in laboratory conditions are represented in comparative graphics (Fig. 6 and Fig. 7).

The paper was developed in the period of internal research project at Technical University of Cluj-Napoca, with the reference code number UTCN 11/1.2/2015

References

1. A.K. Agarwal, "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines." Progress in Energy and Combustion Science, 33, pp. 233-271, 2007.
2. C. Cheng, C. Cheung, T. Chan, S. Lee, C. Yao, "Experimental investigation on the performance, gaseous and particulate emissions of a methanol fumigated diesel engine," Science of the Total Environment, 389, pp. 115-124, 2008.
3. D. Baldean, "Studies and researches concerning modeling the combustion process in compression ignited engine in biodiesel use conditions for improving engine's performances" Doctoral thesis, UTPress, 2011.
4. D. Baldean, et al "Experimental research regarding the possibility of biofuel fumigation supply method on a single cylinder compression ignited engine." in CONAT 2016 International Congress of Automotive and Transport Engineering, ISBN 978-3-319-45447-4, DOI 10.1007/978-3-319-45447-4, S.I P. 2017
5. E. Sadeghinezhada, S.N. Kazia, Foad Sadeghinejadb, A. Badarudina, Mohammad Mehralic, Rad Sadria, Mohammad Reza Safaeia, "A comprehensive literature review of bio-fuel performance in internal combustion engine and relevant costs involvement," Ren. and Sustain. En. Rev., 30, pp. 29-44, 2014.
6. F. Mariasiu, N.V. Burnete, D. Moldovanu, B.O. Varga, C. Iclodean, L. Kocsis, "Effects of bioethanol ultrasonic generated aerosols application on diesel engine performances." Thermal Science, Vol. 19, No. 6, pp. 1931-1941, 2015.
7. M. Abu-Qudais, O. Haddad, M. Qudaisat, "The effect of alcohol fumigation on diesel engine performance and emissions." Energy Conversion and Management, 41, pp. 389-399, 2000.
8. N. Bataga, "Thermal engines. Practical works" (Motoare termice. Lucrari practice) I.P.C-N., pp. 57-60, 1988.
9. N.C. Surawski, B. Miljevic, B.A. Roberts, R.L. Modini, R. Situ, R.J. Brown, et al. "Particle emissions, volatility, and toxicity from an ethanol fumigated compression ignition engine." Environmental Science & Technology, 44, pp. 229-235, 2009.
10. Z. Zhang, C. Cheung, T. Chan, C. Yao, "Emission reduction from diesel engine using fumigation methanol and diesel oxidation catalyst" Science of the Total Envir. 2009, 407, 4497-4505.
11. Z.H. Zhang, K.S. Tsang, C.S. Cheung, T.L. Chan, C.D. Yao Effect of fumigation methanol and ethanol on the gaseous and particulate emissions of a direct- injection diesel engine. Atmospheric Environment 2011, 45, 2001-2008.