HYDROCARBON EMISSIONS FROM BIOFUEL BASED ON RAPESEED OIL COMPARED TO DIESEL FUEL IN DIESEL ENGINE D-2402

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Abstract: *Biofuels are a very attractive alternative to conventional fuel (diesel fuel) in their use on medium power diesel engines. The effects of using on Diesel engines have been intense studied the engine performances and emissions resulting from use as fuels. The hydrocarbons (HC) emitted by a diesel engine are complex mixtures of unburned and partially burned fuel components in the gaseous and liquid phases, containing dangerous compounds for both the environment and human health. The purpose of this study was to identify from experimental researches the emissions of hydrocarbons using as fuels based on rapeseed oil compared with diesel fuel. This engine type (engine D-2402) equipped the middle power vehicles with different destinations and implicitly with different operating regimes and loads. The engine used in the experimental test equiped some tractors in Romania and the supply unit adapted as the case to use biofuels. Fuels used in experimental research were mixtures of rapeseed oil, rapeseed methyl ester and diesel in different proportions, namely: 80% diesel fuel - 20% rapeseed oil, 50% diesel fuel - 50% rapeseed oil, 25%diesel fuel - 75 % rapeseed oil, 100% rapeseed oil, 100% rapeseed methyl ester (RME) and 100% diesel fuel as (reference fuel). Worldwide research on the use of biofuels in the medium-power diesel engines has underlined the immediate results of using the biofuels on consumption problems, pollution and wear of engine parts. Results and conclusions issued in the work are possible due to the support of the research project co-funded by the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013. The theme and direction of approach in this paper represents an innovation in the field of national research. The novelty of these experiments refers to the fuel blends used in the experimental tests and to the importance of results on emissions of hydrocarbons. Practical implications of this work have applicability on the possibility to use these cheaper classes of biofuels in diesel engines in order to reduce hydrocarbon emissions into the atmosphere.*

Key words*: diesel fuel, crude rapeseed oil, rapeseed metyl ester, hydrocarbons emissions.*

INTRODUCTION

It can be said that the energy problem is one of the most controversial today, it's also taking care to energetics, various forms of energy consumers, politicians and not at least the experts. It's solving requires a global solution, uniform very difficult so that no nation can solve on its own. As such, representatives from most UN member countries reunited in Convention on Climate Change (United Nations Framework Convention on Climate Change, UNFCCC) developed in December 1997 in Kyoto (Japan) a document of major importance. The Kyoto Protocol provides for the reduction emissions significantly, confirming the indissoluble link between the quality of life, quality production and energy consumption (COX, P.M. et. col., 2000).

With the Kyoto Protocol, developed countries are to reduce their greenhouse gas emissions in the period 2008–2012 by roughly 5% compared to the 1990 level.

Diesel engine emissions are related to quality characteristics of diesel fuels. The main pollutants emitted from diesel engines is unburned hydrocarbons, solid particles, aldehydes, polycyclic aromatic hydrocarbons, carbon monoxide, nitrogen oxides (BURNETE, N. 2008).

Diesel combustion is characterised by lean air-to-fuel ratios, which lead to very low total hydrocarbon (THC) and carbon monoxide (CO) emissions. On the other hand, the high combustion temperature is responsible for increased nitrogen oxides (NOx) production, while the diffusion combustion of fuel is responsible for elevated emissions of particulate matter (PM), compared to gasoline (CHAPMAN, L., 2007).

Hydrocarbons (HC) are released into the atmosphere as a result of incomplete combustion of fossil fuels, as well as fuel evaporation. According to the EPA (USA Environmental Protection Agency), 47% of hydrocarbon emissions in the atmosphere can be attributed to on-road and off-road vehicles. The strong odor associated with diesel emissions is due to the presence of hydrocarbons.

When hydrocarbons combine with NOx and sunlight, ozone is formed. This is a serious form of air pollution and a key component of smog. The brown haze of smog that plagues many urban areas causes irritation and damage to eyes, skin and lungs. It dries out the protective membranes of the nose and throat, interfering with the body's ability to fight infections. Some hydrocarbons are also considered toxic, causing serious health problems such as cancer or death.

A large number of experiments were carried out with biodiesel as a replacement of diesel engine fuel by researchers from various parts of the world. The advantages, challenges and technical difficulties about using vegetable oils were summarized by RAMADHAS et al., 2004. AGARWAL, 2007 summarized the production, combustion characteristics, engine tribology investigations and economical feasibility of biodiesel. It is recognized that there is a substantial reduction in hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM) (with the exception of NOx emission) when diesel engine is fueled with biodiesel (http://www.epa.gov/otaq/models).

The use of crude rapeseed oil fuel in diesel engines usually requires modification of engine or fuel system components because it has a much higher density and viscosity than diesel fuel (CORDOȘ, N., BURNETE, N, 2003). If crude oil is to be used with diesel in a dual fuel mode are necessary modifications that include additional fuel tank, a system for switching between the two fuels, and a heating system. Another alternative is to use the crude oil exclusively. Modifications would include an electric pre-heating system for the fuel, an upgraded injection system and the addition of glow plugs in the combustion chamber as the vegetable oil is not highly flammable.

Examples of investigations in the field of crude oil as fuel use are researches carried out in Turkey to evaluate the potential of using vegetable oil fuels as a fuel for diesel engines (ALTIN, R., 2001), emission tests performed on the test bench with rapeseed oil fuelled tractor Deutz-Fahr in Germany (THUNEKE K., 2006). Comparative bench testing of a direct injection unmodified diesel engine operating on neat rapeseed oil and its blend with petrol was performed in Lithuania (LABECKAS, G. & SLAVINSKAS, S, 2009).

The aim of this paper is to determine and observe the evolution of the hydrocarbon emissions in case of using the fuels based on rapeseed oil on a medium-power diesel engine compared to diesel fuel.

MATERIAL AND METHODS

The samples that have been used for experiments have been: diesel, the crude rapeseed oil, mixtures between crude rapeseed oil, rapeseed metyl ester and diesel:

- 100 %diesel fuel;
- 100% rapeseed metyl ester (RME);
- 80% diesel fuel - 20% crude rapeseed oil (80D_20R);
- 50% diesel fuel - 50% crude rapeseed oil (50D_50R);

- 25% diesel fuel - 75% crude rapeseed oil (25D_75R);
- 100% crude rapeseed oil.

The biofuel derived from rapeseed oil is slightly poorest than diesel in terms of carbon (8.98%) and hydrogen content (0.79%).

The presence of oxygen in biofuels based on rapeseed oil (~ 10%) favors the engine combustion. It also notes the total absence of sulfur - which leads to the reduction of chemical pollution (do not contribute to emissions of SO_2).

Table 1 shows the main physico chemical properties of biofuels based on rapeseed oil and diesel fuel. [2].

Tabelul 1

Physico chemical properties of biofuels based on rapeseed oil and diesel fuel

Physico chemical properties	**Rapeseed oil**	**Rapeseed methylester**	**Diesel fuel**
Density, 20 ºC [kg/dm^3]	0.92	0.88	840
Kinematic viscosity, 20 °C [mm^2/s]	74	6.3	4…6
Flash point, [ºC]	317	184	80
Cetane number	40	51	50
Calorific value, [MJ/kg]	37.6	37	41.8

Mounting of the engine on test bench has made taking in regard the achievement of conditions that are more closely resemble those existing in the normally exploitation on tractor by intermediary of shock absorbers. D-2402 engine characteristics are summarized in Figure 1 and Table 2.

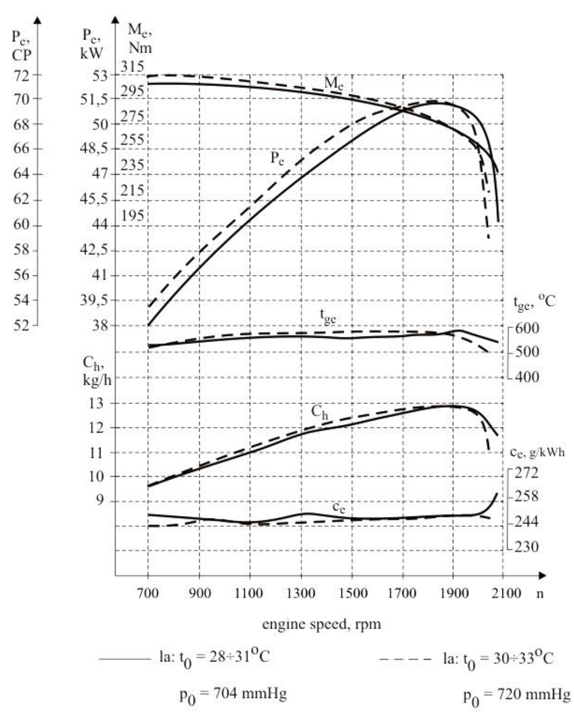

Figure 1. Full-load speed characteristic (χ=1,1) of D-2402engine

Tabelul 2

The main technical characteristics of the engine used in experimental tests

Engine type	**D-2402**
Number of cylinders	4
Cylinder diameter, mm	110
Stroke, mm	130
Engine capacity, cm^3	4760
Compression ratio	17:1
Injection pressure, daN/cm^2	175±5
Injection timing advance	24°
Effective power, kW	51,5
Nominal speed, rot/min	1800
BSFC – Brake Specific Fuels Consumption, g/kWh	244

The experimental stand (Fig. 2) was equipped with an diesel engine, hydraulic brakes and exhaust analyzer type *"BEA 350 DTM"*.

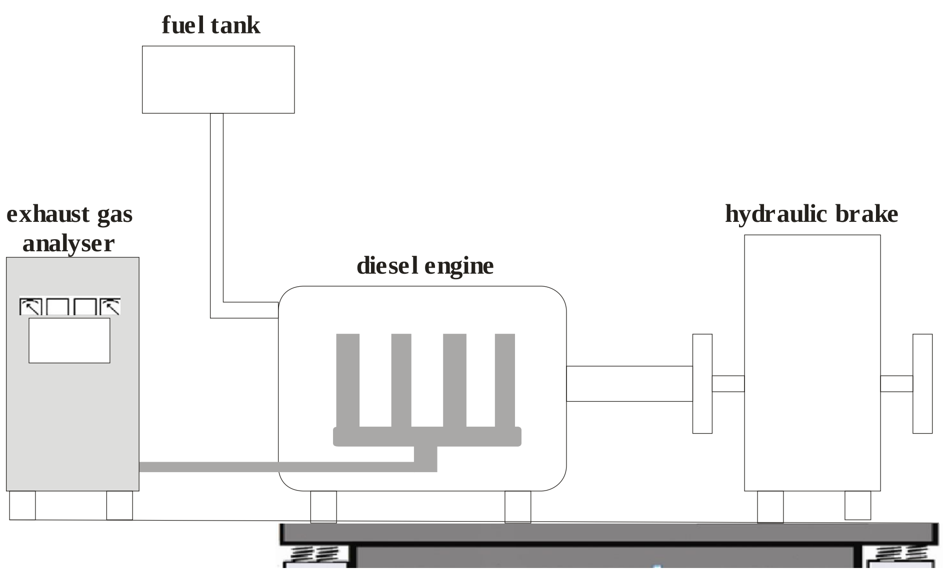

Figure 2. The scheme of experimental stand and positioning of exhaust analyzer

For measurements the polluant emissions in case of diesel engine supply with blends have been used a exhaust analyzer *"BEA 350 DTM"*. "*BEA 350"* is a modular system for measurement the pollutants emitted by diesel and Otto engines. This analyzer use an opacimeter named *RTM 430* which is a dynamic partial-flow measuring instrument for the continuous measurement of exhaust gas opacity (Fig. 3). It is used for certification of emissions engines.

Database of exhaust gas analyzer allows comparisons between real values (measured) and nominal (manufacturer specified). Range and precision of the analyzer is presented in Table 3.

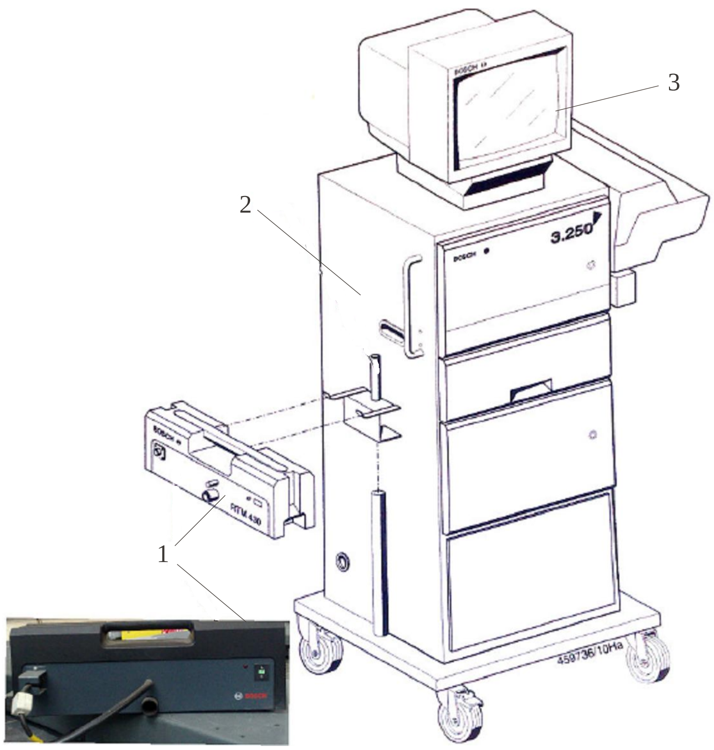

Figure 3. Exhaust analyzer and opacimeter
1. opacimeter RTM 430 and its positioning; 2.exhaust analyzer BEA 350; 3. display for results

Table 3

Measuring range and precision of the apparatus for poluants

Exhaust gas measuring module		
Measured pollutants	**Measuring range**	**Precision**
CO	0,000 - 10,00 % vol	0,001 % vol
CO_2	0,00 - 18,00 % vol	0,01 % vol
HC	0 - 9999 ppm vol	1 ppm vol
O_2	0,0 - 22,00 % vol	0,01 % vol
λ(air fuel ratio)	0,500 - 9,999	0,001
NO	0 - 5000 ppm vol	<= 1 ppm vol

The experimental tests on pollution produced by diesel engines fueled with crude rapeseed oil and various blends were carried out according to EU Directive [11].

The hydrocarbons emissions level in diesel engine fueled with blended based on rapeseed oil compared to diesel fuel in engine was analyzed on six engine loads (regimes): □= 0.92, 0.86, 0.82, 0.78, 0.73, 0.68.

RESULTS AND DISCUSSIONS

The figures 4-9 represents the hydrocarbons emissions level for the blends based on rapeseed oil use on diesel engine compared to diesel fuel on six engine loads (regimes) □=0.92, 0.86, 0.82, 0.78, 0.73, 0.68.

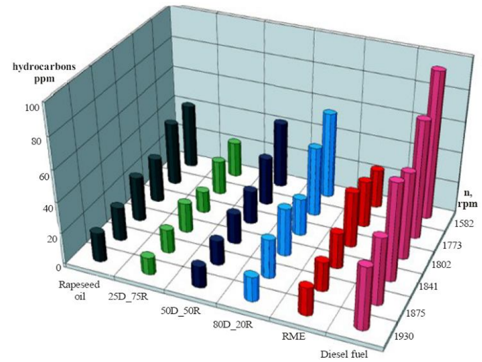

Figure 4. Variation of hydrocarbon emissions for □ = 0.92 load regime

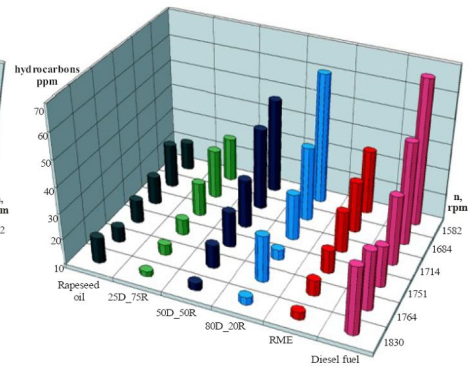

Figure 5. Variation of hydrocarbon emissions for □ = 0.86 load regime

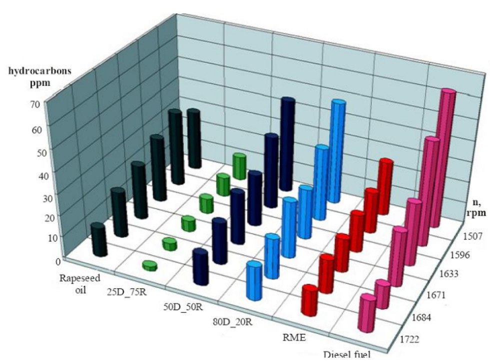

Figure 6. Variation of hydrocarbon emissions for □ = 0.82 load regime

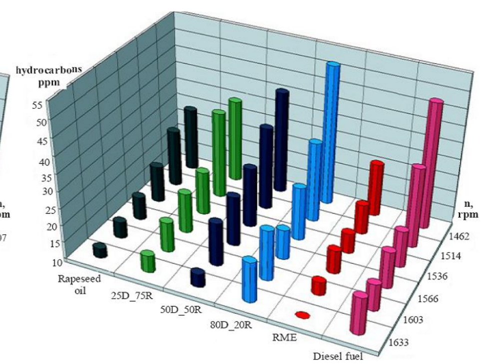

Figure 7. Variation of hydrocarbon emissions for □ = 0.78 load regime

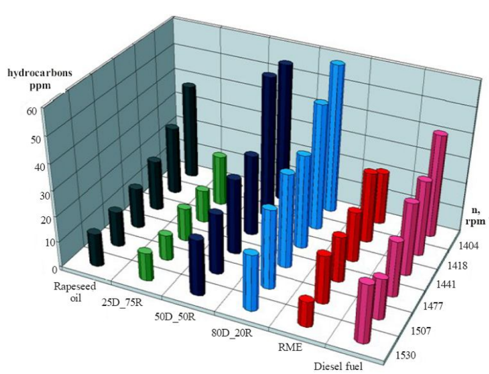

Figure 8. Variation of hydrocarbon emissions for □ = 0.73 load regime

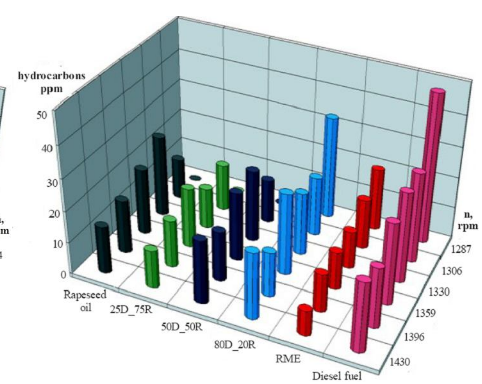

Figure 9. Variation of hydrocarbon emissions for □ = 0.68 load regime

CONCLUSIONS

The tables 4 have synthesized hydrocarbon emissions values determined from experimental research on the blends based on rapeseed oil compared to diesel fuel.

Table 4

The evolution of hydrocarbon emissions of biofuels based on fuels rapeseed oil compared with diesel fuel

Load regime	Fuels tested	Emissions of hydrocarbon difference
□=0.92	Crude rapeseed oil	**- 51,2 %**
	RME	**- 59,51 %**
	25%D_75%R	**- 72,11 %**
	50%D_50%R	**- 60,85 %**
	80%D_20%R	**- 47,18 %**
□=0.86	Crude rapeseed oil	**- 50,2 %**
	RME	**- 44,17 %**
	25%D_75%R	**- 51,40 %**
	50%D_50%R	**- 30,12 %**
	80%D_20%R	**- 26,50 %**
□=0.82	Crude rapeseed oil	**- 19.38 %**
	RME	**- 44,89 %**
	25%D_75%R	**- 79,59 %**
	50%D_50%R	**- 15,81 %**
	80%D_20%R	**- 13,26 %**
□=0.78	Crude rapeseed oil	**-25,15 %**
	RME	**- 37,42 %**
	25%D_75%R	**- 7,97 %**
	50%D_50%R	**+ 1,84 %**
	80%D_20%R	**+ 9,2 %**
□=0.73	Crude rapeseed oil	**- 20,49 %**
	RME	**- 27,95 %**
	25%D_75%R	**- 44,16 %**
	50%D_50%R	**+ 36,02 %**
	80%D_20%R	**+ 46,58 %**
□=0.68	Crude rapeseed oil	**-20,4 %**
	RME	**- 53,75 %**
	25%D_75%R	**- 40,8 %**
	50%D_50%R	**- 24 %**
	80%D_20%R	**- 23,12 %**

Relative to level of hydrocarbons emitted from fuels based on rapeseed oil has yielded values mostly smaller than those measured when using diesel fuel.

Hydrocarbons in the exhaust gases are due to conditions caused primarily by the impossibility of flame propagation front in fuel mixture. When fuel reaches the combustion chamber wall, it suffers slow chemical transformation, with the formation of hydrocarbons due to insufficient combustion. Another cause of formation of hydrocarbons is that the fuel droplets are not receiving enough oxygen. In the absence of sufficient oxygen necessary for combustion, hydrocarbons are formed.

- a reason of that is the rapeseed oil composition having the higher percentage of oxygen (approx. 10% more) therefore has lower emissions of hydrocarbons, for most of engine load , which does not have oxygen in composition.
- also, it was found that hydrocarbon emissions are much better values for rapeseed oil than for diesel fuel emission values, reaching up to 51.2% more lower to rapeseed oil at 0.92 engine load. At the same regime load, RME emits hydrocarbons up to 59.51 lower than diesel.
- emissions of hydrocarbons using biofuels at a lower engines load, has a increase

tendency than at higher engines load due to the lower thermal engine regime for low speeds.

➢ in the case of biofuels made from rapeseed oil is found that the emissions of hydrocarbons are lower than diesel. The explanation is found in their chemical differential composition. The more diesel fuel in the participation blend increase, the emissions of hydrocarbons increase.

The experimental test showed that biofuel based on crude rapeseed oil is viable in terms of environmental pollution for its use as fuel. This type of fuel emits fewer hydrocarbons emissions and contributes to reducing the air pollution.

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BIBLIOGRAFY

1. AGARWAL AK., Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Prog Energy Combust;33:233–71, 2007
2. ALTIN, R., ÇETINKAYA, S., SERDAR, H.Y., The potential of using vegetable oil fuels as fuel for diesel engines. Energy Conversion and Management 42, pp. 529–538, 2001
3. BURNETE, N. and others, Diesel engines and biofuels for urban transport (in romanian), Publishing House Mediamira, ISBN 978-973-713-217-8, 1054 pg., 2008
4. CHAPMAN, L., Transport and climate change: a review. Journal of Transport Geography 15, 354e367) 2007
5. CORDOȘ, N., BURNETE, N., The analyses of the main proprieties of fuels based on rape oil, compared to Diesel fuel, în vol.: The 7th International Conference FUEL ECONOMY, SAFETY and RELIABILITY of MOTOR VEHICLES, ESFA, Bucharest, pag. 125-128, 6 fig, 4 ref. biblio., ISBN 973-8449-11-1, 2003
6. COX, P.M., BETTS, R.A., JONES, C.D., SPALL, S.A., TOTTERDELL, I.J., Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature 408, 180–184, 2000
7. LABECKAS, G. & SLAVINSKAS, S., Performance and Emission Characteristics of Off-Road Diesel Engine Operating on Rapeseed Oil and Petrol Blends. In: Proceedings of the8th International Scientific Conference 'Engineering for Rural Development'. Latvia, University of Agriculture, Jelgava, pp. 135–140, 2009
8. RAMADHAS As, JAYARAJ S, MURALEEDHARAN C., Use of vegetable oils as IC engine fuels – a review. Renew Energy;29:727–42, 2004
9. THUNEKE K., Rapeseed Oil Fuel – Production, Quality Demands and Use Experience. Biomass for Energy – Challenges for Agriculture. [online] [cited 10-04-2009], 2006
10. * * * EEC Directive 88/77, EEC L36 Journal Officiel, February 8, 1988.
11. * * * A comprehensive analysis of biodiesel impacts on exhaust emissions. Draft Technical Report, EPA420-P-02-001, http://www.epa.gov/otaq/models/, 2002