

COMPARATIVE RESEARCH OF ORGANIC COMPONENTS OF EMISSIONS USING COMPRESSION IGNITION ENGINE FUELLED WITH DIESEL OIL OR RAPE SEED METHYL ESTERS

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Abstract

The results of comparative research of the organic components in the exhaust emissions of the CI engine fuelled with Diesel oil or rape seed methyl esters (RSME) were presented in this paper. The experimental works reported here was carried out on the turbocharged, four cylinder, water cooled, CI engine, T 370 type (80 kW rated power at 2400 rpm, 400 Nm maximum torque at 1440 rpm, bore/stroke – 110/120 mm, displacement volume – 4560 cm³, compression ratio 17:1). The Signal equipment and AVL equipment were used for regulated exhaust emissions measurements and Hewlett Packard chromatograph type HP 5890 II for measurements of organic species emissions. The research was carried out under engine full load at maximum torque speed and at rated power speed. Using special equipment and normalized procedures the chromatographic test samples were collected. The 83 species were identified in HC emissions at these experiments but only the benzene, toluene and acetaldehyde were the components which were detected in substantial quantity. The research results show that the percentage emissions of individual components in total emissions of HC were weakly dependent on the used fuel. However in the case of RSME engine feed the HC emissions were lower than those of the engine fuelled with Diesel oil and total emissions of their components were lower. Concluding, emissions from RSME combustion are less harmful than emissions of the engine fuelled with Diesel oil.

Keywords: *CI internal combustion engines, motor fuels, toxic exhaust emissions*

1. Introduction

Many reasons of the usage of biofuels as the sources of energy are considered. The most important reasons are the limitation of the emissions to the atmosphere of greenhouse-gases and the limitation of the output of the fuels from fossil sources because the world has a finite supply of crude oil. The Conference on Climate Changes in Kyoto, in the year 1997, paid attention on the sharp increase of the human-caused emissions greenhouse gases, what brought to the agreement of the most of the high developed economy states about the self-limitation of the CO₂ emission to the atmosphere. A greatest concern of this agreement is that the countries being greatest emitters of greenhouse-gases: Russia, China, India, U.S.A. did not accede to him. The Climatic Top in Copenhagen, in 2009, whereon one foresaw the introduction of further limitations of the emission CO₂ was completed with the defeat also because these limitations were struck into developed countries economy, which at present build up their own industry and foresee the essential enlargement of the CO₂ emission. They would have to obtain so constant compensations in exchange for the resignation from the industrialization.

Most seriously to the problem of the limitation of the CO₂ emission was treated by the European Union country which committed themselves to cut the CO₂ emission to the year 2012 about 8,1 percent accepting as the year of the reference the year 1990. In this strategy the utilization of biofuels plays the crucial role, because the EU countries possess large excess of agricultural productions but their energy-needs in about 75 percent are based on the fossil fuels import. An advantage of biofuels is that in the full cycle, in connection with the assimilation process of plants, they would be able to have the zero-balance of the CO₂ emission.

It is necessary so to be ready on this time after when natural resources will disappear, or their exploitation will drop to the drastic level and only sources for production will be natural renewable sources, e.g.: the solar power, the hydropower, the energy of winds and biofuels. Among these energy sources only biofuels have the form foreseeable and possible to planning, but other kinds of the energy have an accidental form and their use take the hazard of the lack of continuous deliveries.

The combustion process of engine petroleum fuels is sufficiently well recognized but in spite of this it exists the row of concerns were not explained to the end in the combustion mechanism. This more unknowns one can be noticed in the combustion mechanism of the biological origin fuels who's the combustion mechanism are the subject of the study for relatively long years. This study is not always carrying out with the full consequence. The mass-using of the biofuels can result the emergence of new constituents of the emission to the atmosphere whose the contents should be limited because of their harmful and big quantity. Therefore the aim of research realized within this framework was determination comparatively the composition and the components contents of the HC emission, in the exhaust emissions of the engine fuelled with the RSME or Diesel oil.

The researches realized within the framework of this work were carried out with using of the turbocharged four strokes, and four-cylinder water cooled, compression ignition engine fuelled with the RSME or Diesel oil. A subject of this study was the composition of nonburned combustion gases in tailpipe emissions of the engine, particularly the contents of individual species in the HC emission. In the all mass of organic components in exhaust gases (the emission HC) one there were favourable that components of those contents were highest, and their influence on human health was the biggest. One ought to be noticed that investigations are very tedious and time-consuming work. They carried out with the use of the most modern, high-quality, the chromatographic equipment.

2. Research object methodology

Turbocharged, four-stroke, four-cylinder, water cooled, compression ignition automotive engine, type T370, was the object of this study with the following specifications:

- Bore/stroke [mm] 110/120,
- Displacement volume [cm³] 4560,
- Compression ratio 17:1,
- Rated power [kW] 80,
- Rated power speed [rpm] 2400,
- Maximum torque [Nm] 400,
- Maximum torque speed [rpm] 1440,
- Fuel pump PEW4-07 (in line),
- Injectors Nk-3140,
- Turbocharger B65/5.65.

T370 engine was installed on the test stand (Fig. 1) at the Institute of Aviation and coupled with the Schenck eddy-current dynamometer, type W450. All the necessary measuring and controlling systems were mounted for testing. The proper research was preceded by preliminary tests using the producer regulations, during which the characteristics of the engine power output versus engine speed at full load, with Diesel oil or RSME were determined. The specifications of the used in experiment fuels can found at references [10].

Because of the characteristics of an engine fuelled with fuel other, than the fuel specified in the engine manual, may be more favourable with other regulations than the producer regulation, the optimization investigations were performed. These researches were resulted in the selection of the injection timing the best from the point of view of maximum engine output. The tests were carried out at conditions of engine maximum torque speed (1440 rpm, full load) and rated power engine speed (2400 rpm, full load).

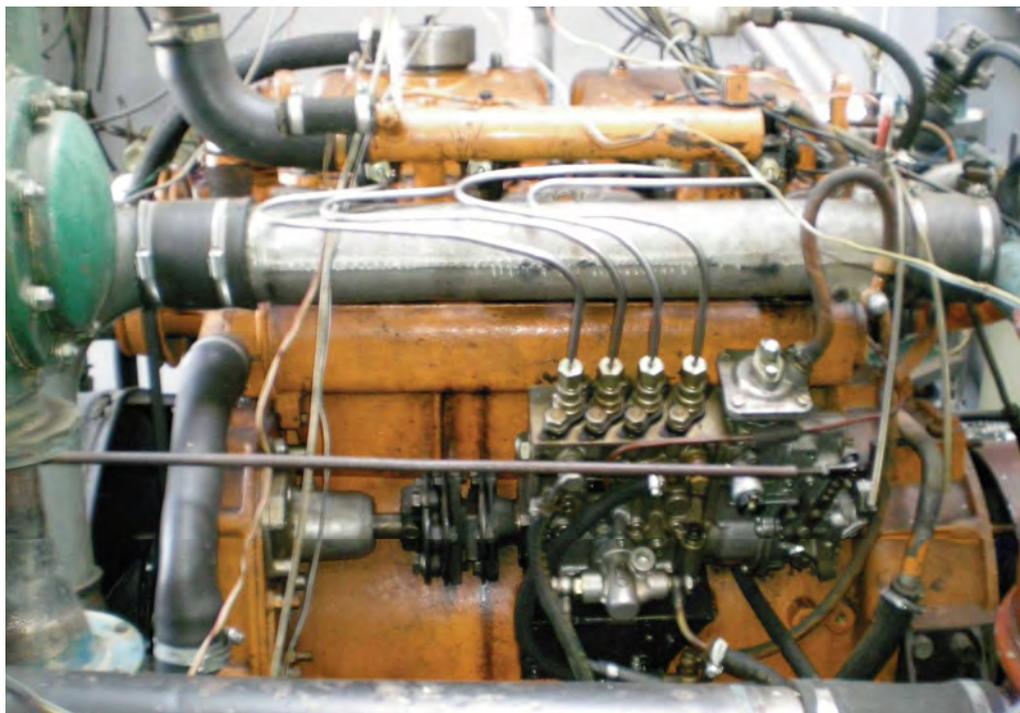


Fig. 1. View of tested engine, type T370

3. Research of hydrocarbon emissions composition

The Hewlett-Packard gas chromatograph type HP-5890 II, equipped with mass detector type HP-MSD-5972, the chamber injector (Split/splitless type), and a capillary column HP-PONA with a length of 50 m, diameter 0.2 mm, and stationary phase film injected on the surface with thickness 0.5 μm for measurements of the hydrocarbons constitution was used.

Samples for hydrocarbons analysis were drawn from exhaust system, through metering nozzle and calibrated divider using the suction pump (type 224-PCEX4 U.S. manufactured by SKC LTD) in the amount of 5 dm^3 , during the tested engine operations. The exhaust gases were directed to tubes filled with activated carbon (manufactured by SKC LTD U.S. Cat. No. 226-01) to identify the hydrocarbons. The exhaust gases for the aldehydes identification of the amount 0.5 dm^3 were collected in tubes filled with 2-hydroksymethylpiperodine (manufactured by SKC LTD U.S. Cat. No. 226-117). Then the samples were subjected the chromatographic analysis to identify the individual species of an emission. At the beginning of the tests gas chromatograph was calibrated by injecting the standard mixture into the chromatography column (pure sorbent tube) and then the tube with exhaust gas sample was fixed in the chromatograph.

Figure 2 shows the typical mixture chromatogram for aldehydes derivatives. Each peak in the chromatograms, after respective retention time, refers to definite species. After respective retention times the particular aldehyde was detected, e.g. after 20.90 min. acetaldehyde, after 21.03 min. formaldehyde, etc.

The samples of exhaust gas chromatograms taken during engine operation at full load, 2400 rpm, when the engine was fuelled with Diesel oil or RSME, where presented comparatively in Fig. 3. The retention time on abscissa, range from 8.00 minute to 12.00 minute is characteristic for benzene and toluene. The retention time 8.60 minute for benzene and 11.41 minute for toluene.

The samples of the exhaust gas chromatograms taken during engine operation of full load, at maximum torque speed (1440 rpm) and rated power speed (2400 rpm), when the engine was fuelled with RSME, in the Fig. 4 were compared. The characteristic time for aldehydes from 20.20 to 21.40 minutes. The peaks appear after the retention time 20.90 minutes are characteristic for acetaldehyde.

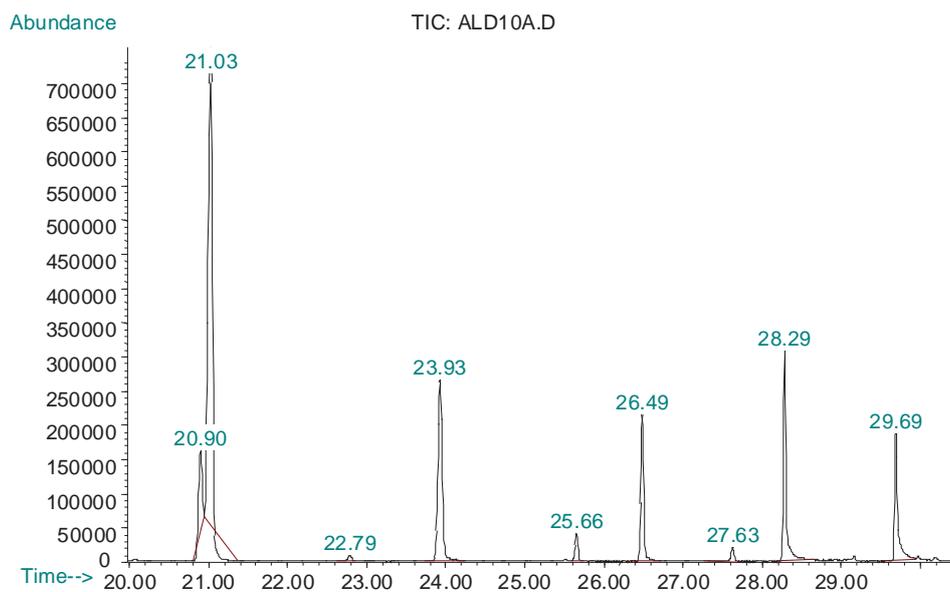


Fig. 2. Chromatogram of derivatives standard mixture aldehydes: Retention times: 20.90 min - acetaldehyde HMP, 21.03 min - formaldehyde HMP, 23.93 min - acrolein and propionic aldehyde HMP, 26.49 min - n-butyric aldehyde HMP, 28.29 min - n-valeric aldehyde HMP, 29.69 min - aldehyde Hexanoic HMP

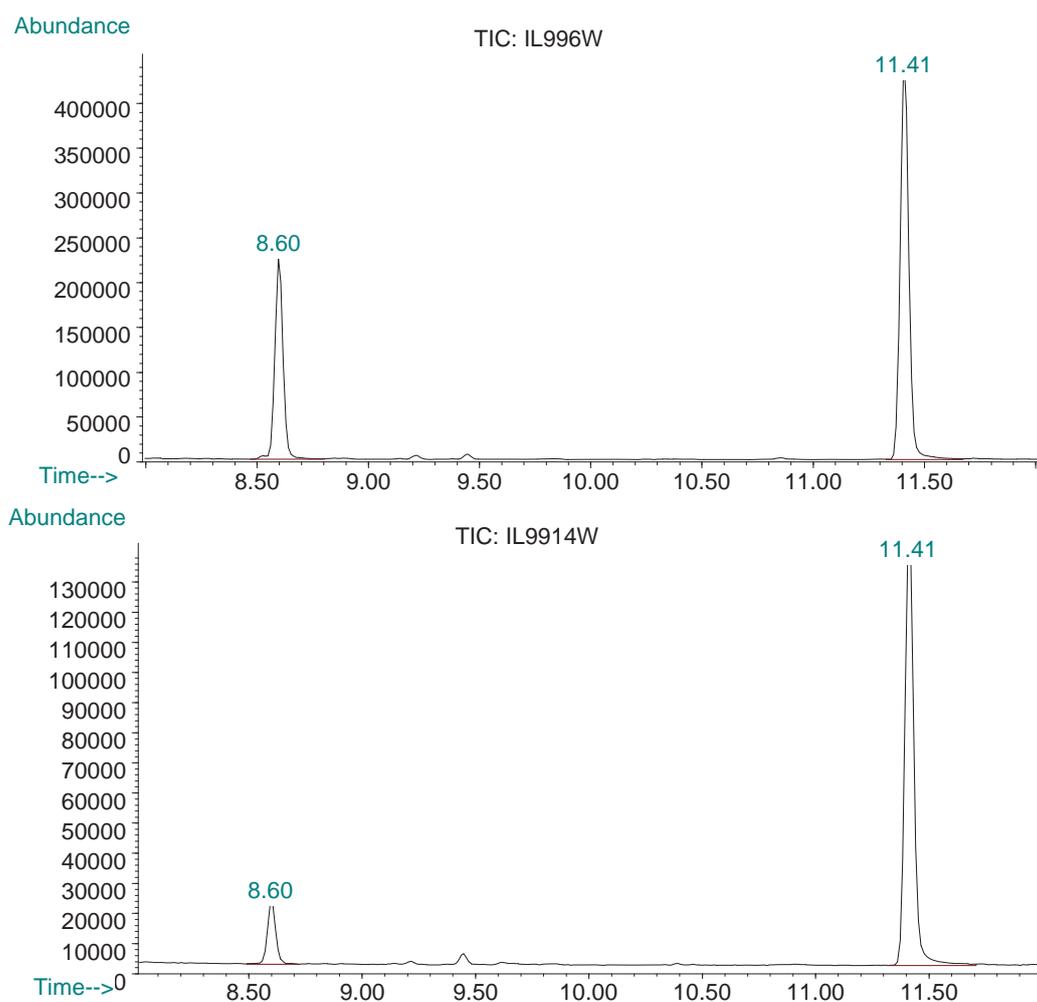


Fig. 3. The samples of exhaust gas chromatograms taken during engine operation at full load, 2400 rpm Diesel oil top, RSME bottom

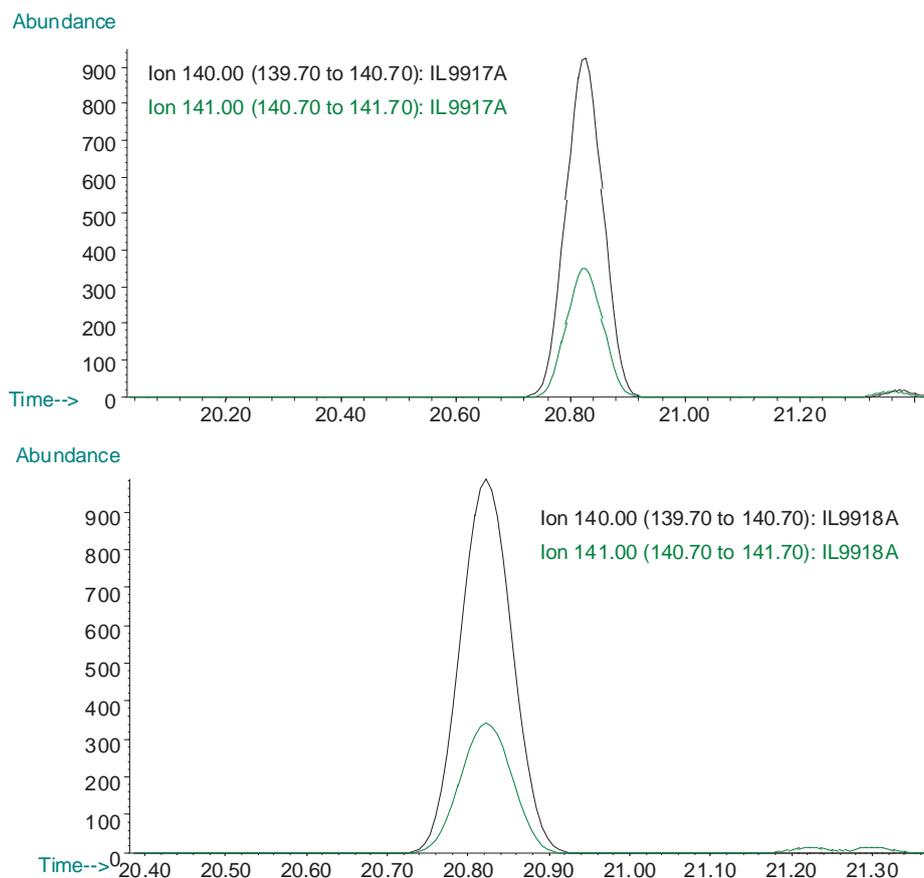


Fig. 4. Comparisons of the chromatograms for the engine operated at full load fuelled with RSME. RSME, top 1440 rpm, bottom 2400 rpm

The diagrams in Fig. 5 to 10 summarize the results from numerous gas chromatograms concerning three substances only, because these substances appeared with the highest concentrations at HC emissions, in exhaust emissions of operating test engine.

In Fig. 5 was compared the benzene specific emission at maximum torque conditions (1440 rpm, full load). If the engine was fuelled with RSME the benzene emission was two time lower than the engine fuelled with Diesel oil was.

In Fig. 6 was compared the benzene specific emission at rated power conditions (2440 rpm, full load). If the engine was fuelled with RSME the benzene emission was 60 percent lower than the engine fuelled with Diesel oil was.

In Fig. 7 the toluene specific emission at maximum torque conditions (1440 rpm, full load) was compared. If the engine was fuelled with RSME the toluene emission was two time lower than those of the engine fuelled with Diesel oil.

In Fig. 8 was compared the toluene specific emission at rated power conditions (2440 rpm, full load). If the engine was fuelled with RSME the toluene emission was lower about 22 percent than those of the engine fuelled with Diesel oil.

In Fig. 9 the acetaldehyde specific emission at maximum torque conditions (1440 rpm, full load) was compared. If the engine was fuelled with RSME the acetaldehyde emission was higher about 18 percent than those of the engine fuelled with Diesel oil. It was the only case in which the engine emission, if the engine was fuelled with Diesel oil, was lower than those of the engine fuelled with RSME at this research.

In Fig. 10 the acetaldehyde specific emission at rated power conditions (2440 rpm, full load) was compared. If the engine was fuelled with RSME the acetaldehyde emission was lower about 31 percent than those of the engine fuelled with Diesel oil.

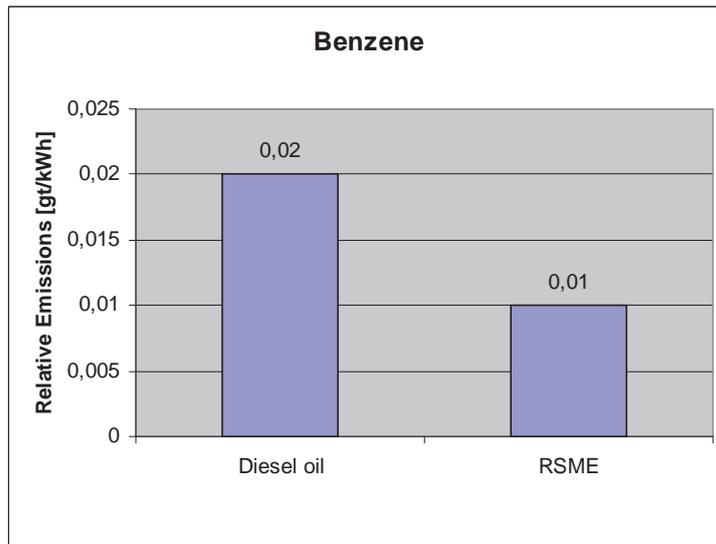


Fig. 5. Comparison of benzene emissions from the engine fuelled with Diesel oil or RSME for: full load, 1440 rpm

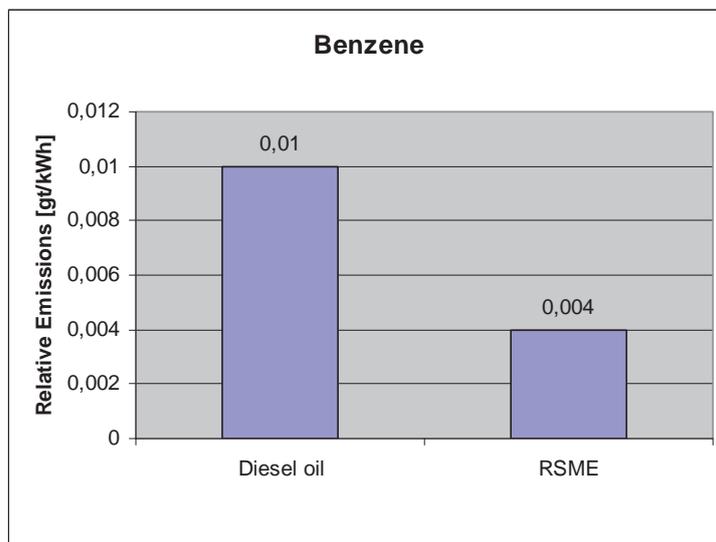


Fig. 6. Comparison of benzene emissions from the engine fuelled with Diesel oil or RSME for: full load, 2400 rpm

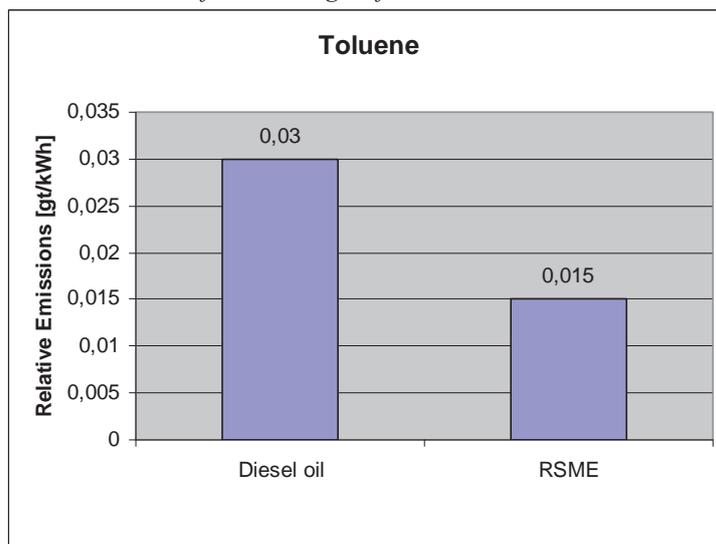


Fig. 7. Comparison of toluene emissions from the engine fuelled with Diesel oil or RSME for: full load, 1440 rpm

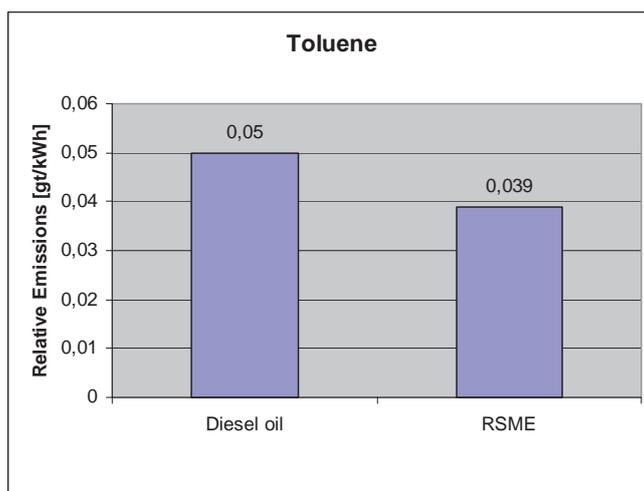


Fig. 8. Comparison of toluene emissions from the engine fuelled with Diesel oil or RSME for: full load, 2400 rpm

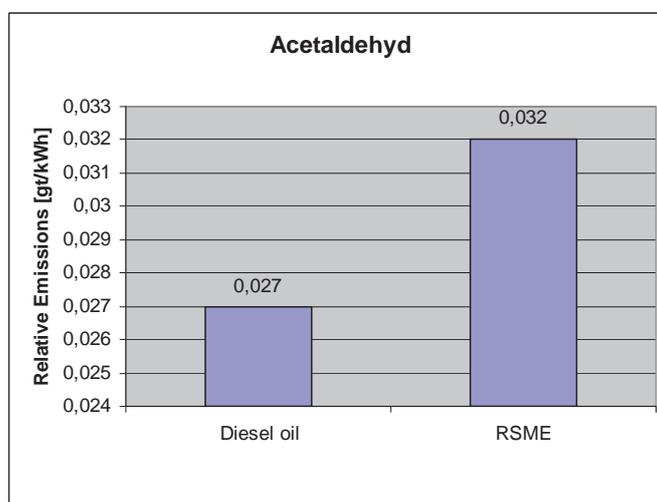


Fig. 9. Comparison of acetaldehyde emissions from the engine fuelled with Diesel oil or RSME for: full load, 1440 rpm

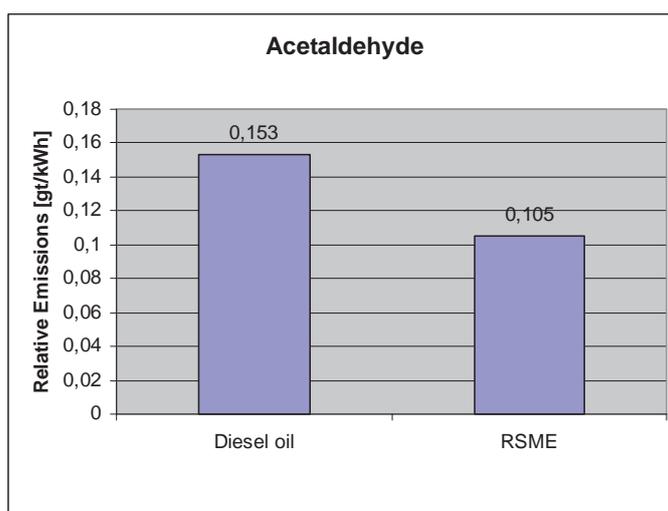


Fig. 10. Comparison of acetaldehyde emissions from the engine fuelled with Diesel oil or RSME for full load, 2400 rpm

During the chromatographic testing of the exhaust gases samples the eighty three organic compounds were identified in HC emissions. The majority of the compounds were trace contents.

Therefore the research were focused on the species which contents were the highest and the most harmful, there are: benzene, toluene and acetaldehyde. Nearly full contents of harmful substances were higher if the engine was fuelled with Diesel oil and therefore the Diesel oil emissions are more harmful than the emissions of the engine fuelled with RSME.

4. Conclusions

1. If the engine was fuelled with RSME the total HC emission was lower about 33 percent than those of the engine operated with Diesel oil, when the engine operated at maximum torque conditions (1440 rpm, full load), but if the engine operated at rated power conditions (2400 rpm, full load) their HC emissions levels was similar.
2. The percentage share of emissions of individual HC species, in total HC emissions, were weakly dependent of the used fuel (Diesel oil or RSME).
3. In these experiments the eighty three (at 55 to 99 percent probability level) particular species in HC emissions were detected at chromatograph curves, but only three constituents were at substantial quantity.
4. Majority of the species which were detected occur trace (minute) quantities and not influenced the total HC emissions.
5. Only benzene, toluene and acetaldehyde in exhaust emissions were revealed at bigger quantity and they became the subject of quantitative research.
6. The total HC emissions of the engine fuelled with RSME were lower than those of the engine fuelled with Diesel oil; the quantity of particular species, in case of fuelling with RSME, was lower.

References

- [1] Boam, D. J., et al., *The Sources of Unburnt Hydrocarbon Emissions from Spark Ignition Engines during Cold Starts and Warm-up*, FISITA Congress, No. C448/064, London 1992.
- [2] Egeback, K., Laurikko, J., Ryden, Ch., *Emission Characteristics when Using Bioethanol as a Fuel for Passenger Cars*, FISITA Congress, No. F98P162, Paris 1998.
- [3] Glassman, I., *Combustion*, Academic Press, San Diego - Toronto 1996.
- [4] Heywood, J. B., *Internal Combustion Engine Fundamentals*, McGraw Hill, New York 1988.
- [5] Jankowski, A., et al., *Rape Seed Oil Methyl Ester Fuel as Alternative Diesel Fuel for High Speed Diesel Engines For Urban Buses*, ICE Vol. 24, Natural Gas and Alternative Fuels for Engines, ASME Transactions 1994.
- [6] Jankowski, A., Sandel, A., *Exhaust Emission Problems of Internal Combustion Engines Fuelled with Biofuels*, Journal of KONES, Internal Combustion Engines, Vol. 10, No. 3-4, 2003.
- [7] Lefebvre, A. H., *The Role Fuel Preparation in Low-Emission Combustion*, Transactions of the ASME, Journal of Engineering for Gas Turbines and Power, Vol. 117, pp. 617-654, 1995.
- [8] Pagowski, Z., et al., *Proecological Fuels for Diesel Engines*, Proceedings of ISATA XXVI, AAL Croydon, Aachen 1993.
- [9] Pagowski, Z., Rusin, M., *Biopaliwa - od kopalń do trójcyfrowego*, Materiały Seminarium pn.: „Paliwa Płynne w Polsce - współczesne wyzwania”, Płock 2000.
- [10] Rusin, M., *Comparison of Unburnt Hydrocarbon Emissions for Diesel Engines Fuelled by Diesel Oil and Rapeseed Fuel*, Journal of KONES, Internal Combustion Engines, Vol. 16 No. 4, 2009.
- [11] Tinaut, F. V., Melgar, A., Bricenda, V. C., *Motor Biofuels, History, Current Status and Future Perspectives*, FISITA Congress, No. F98P081, Paris 1998.
- [12] Warnatz, J., Maas, U., Dible, R. W., *Combustion*, Springer Verlag, Berlin, Heidelberg, New York, 2001.