

THE EFFECT OF DIESEL/ETHANOL BLENDS ON VARIATIONS OF SELECTED COMBUSTION PARAMETER

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Abstract

This paper presents and discusses selected research results of the diesel engine fuelled with blends of: diesel oil (DO), synthetic ethanol (ET) as oxygenated additive and small quantity of fatty acid methyl esters (FAME) used as emulsifier. Content of ethanol in diesel oil was changed in wide range (up to 50%). Addition of 5% by vol. of FAME was constant for each tested mixture. Preliminary tests were focused on influence of fuels blends composition on its combustion process. The main analyzed parameter was mean indicated pressure and its unrepeatability index. Research suggests that diesel oil blended with up to 20% of ethanol can be successfully used for diesel engines feeding. Higher ethanol content in mixture with diesel oil is unfavourable because misfire phenomenon occurs immediately. In this case tested engine works unstable with extremely high toxic gases emission.

Some physical properties of tested fuels, measurement system configuration, Values of mean indicated pressure vs. cycle number for AD3.152 engine fuelled with: pure diesel oil, ET10, ET20, ET30, ET 40, ET50, Variations of unrepeatability index of mean indicated pressure in relationship to kind of tested fuels are presented In the paper. Research shows that tested engine is not possible to operate with using above 40% of ethanol content in diesel oil, as the fuel simply will not ignite.

Keywords: *misfire detection, diesel engine, combustion process, ethanol, alternative fuels*

1. Introduction

In more recent years the economics of ethanol production have become more favourable compared to petroleum fuel costs. For this reason ethanol in gasoline was commercially introduced and is still marketed. In principle ethanol is an excellent oxygenated additive for spark-ignition engines, but it can be blended into diesel oil too. It has to be done with using of special emulsifiers such fatty acid methyl esters (FAME). Such fuel blends are stable in wide range of temperature changes [3].

Ethanol can be produced based on renewable resources such: corn, sugar beet etc, but it is possible to do with using of the wood waste too. The kind of resources and technology used for

ethanol production have an important influence on total (life cycle analysis) CO₂ emission. Some studies suggest that equivalent of CO₂ emission for wood based ethanol equals 35 g/km only, in comparison up to 200 g/km for conventional (crop based) ethanol. The some analysis demonstrates that ethanol production is more energy intensive than conventional petroleum and doesn't reduce greenhouse gas emission significant [2]. It should be noted, that tests show positive influence of ethanol usage on toxic gases reduction. Ethanol blended into diesel fuel can help to reduce PM emission up to 40% and up to 20% in case of CO [1].

Ethanol molecule is straight and its short carbon chain burn cleanly with low soot formation. On the other hand such structures like aromatic compounds have poor ignition quality. For this reason ethanol blended with diesel oil reduces its Cetane Number and special improver may be needed for properly engine operation. Similar problems are connected with ethanol lower values of: lubricity, heating value, viscosity etc. A lot of these unfavourable ethanol properties can be limited with using of small quantity of FAME.

There are a lot of papers where different oxygenated biocomponents were tested as fuel additives for diesel oil [2, 4-9]. In case of Poland and Latvia the most of these papers are focused on FAME fuels in application for diesel engines. Oxygenates such ethanol or ethers aren't so popular in these research still.

2. Tested fuels properties

Tested engine was fuelled with pure diesel oil (DO) and its blends with different volumetric addition of synthetic ethanol. All ethanol/diesel blends were mixed with constant 5% (by vol.) addition of FAME used as emulsifier. Selected physical properties of all tested fuels which were used in these tests are shown in Tab. 1.

Tab. 1. Some physical properties of tested fuels

Properties	Kind of fuel		
	Diesel oil	FAME	Ethanol
Viscosity at 40°C, [mm ² /s]	3.49	4.8	-
Density at 20°C, [g/cm ³]	834	881	752
Heating value of fuel, [MJ/kg]	43.2	37.8	36.4
Heating value of fuel, [MJ/dm ³]	36,0	33.3	27.3
Cetane number, [-]	50	-	-
Copper strip corrosion, [-]	1	1	1
Molecular weight, [g/mol]	~200	~300	102
Autoignition temp, [°C]	~230	-	~310
Flash point, [°C]	62	170	-25
Elementary content, [% by weight]	C	0,86	0.77
	H	0.14	0.12
	O	-	0.11
			0.157

Using above presented fuels, different diesel/ethanol blends with 5% addition of FAME emulsifier were prepared for research. Composition of tested fuels was as follow:

- ET10 contain: 10% ethanol, 85% diesel oil, 5% FAME,
- ET20 contain: 20% ethanol, 75% diesel oil, 5% FAME,
- ET30 contain: 30% ethanol, 65% diesel oil, 5% FAME,
- ET40 contain: 40% ethanol, 55% diesel oil, 5% FAME,
- ET50 contain: 50% ethanol, 45% diesel oil, 5% FAME.

3. Test stand and research methodology

The research was carried out with using of direct injection AD3.152 type engine installed in the laboratory of Institute of Operation and Maintenance of Vehicles and Machines at Technical University of Radom. All research has been done for nominal regulation of engine fuel injection equipment. Tested engine was coupled to water type brake and connected to special type sensors and devices. The schematic of the experimental setup is shown in Fig. 1.

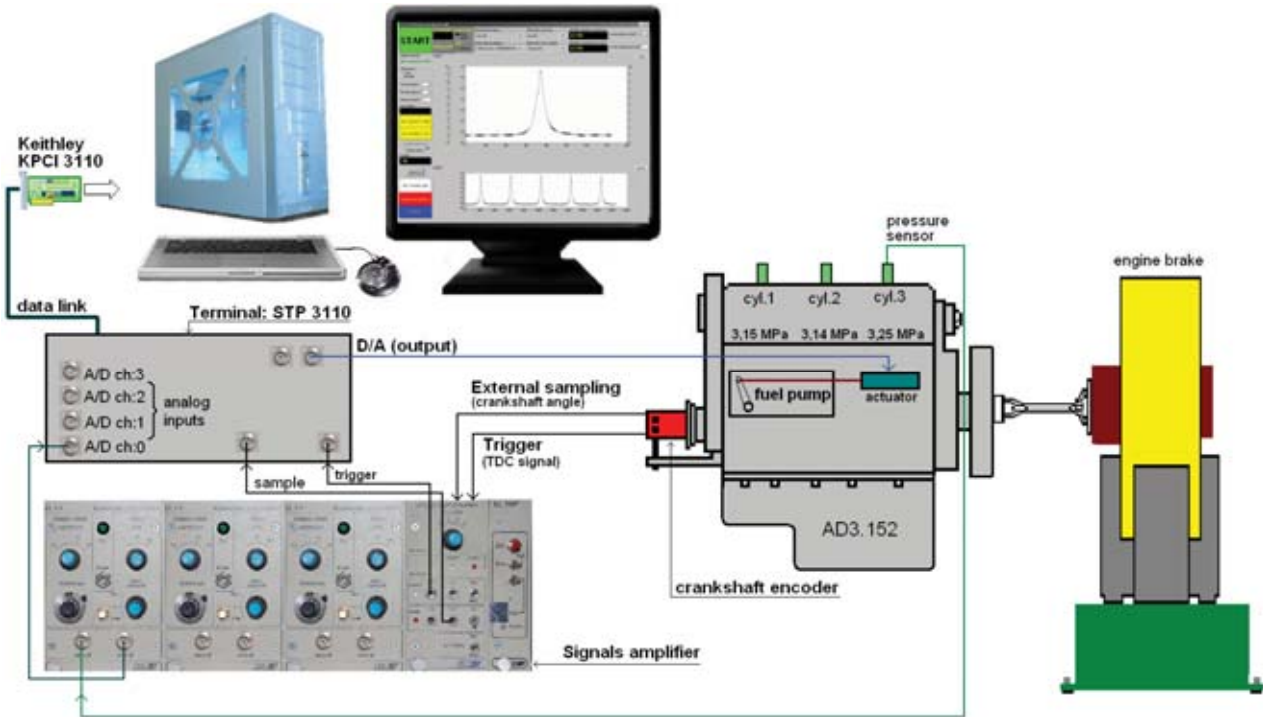


Fig. 1. View of measurement system configuration

The engine cylinder number 3 was equipped with AVL QC34D type quartz pressure transducer. In-cylinder pressure variations were recorded with accuracy of 0,7 deg. of crankshaft angle (CA) with using of INTRON crankshaft encoder. Values of mean indicated pressure have been calculated in each recorded cycle of engine work. Each measurement point contain 1000 cycles. Next, the unrepeatability index X_{p_i} of mean indicated pressure has been calculated using below presented formula [1]:

$$X_{p_i} = \frac{\sigma(p_i)}{\overline{p_i}} = \frac{\sqrt{\frac{1}{k} \sum_{n=1}^k [(p_i)_n - \overline{p_i}]^2}}{\overline{p_i}} \cdot 100\%, \quad (1)$$

where:

$(p_i)_n$ - value of mean indicated pressure calculated in cycle number n,

k - number of all recorded cycles, k=1000,

$\sigma(p_i)$ - p_i standard deviation,

$\overline{p_i}$ - average value of p_i calculated for all recorded cycles.

Each fuels were tested in conditions of engine partial load at torque $N = 120$ Nm and crankshaft rotational speed equal 1200 rpm. Maximum torque for tested engine equals 165 Nm at 1300 rpm.

4. Test results

Variations of mean indicated pressure calculated cycle by cycle for AD3.152 type diesel engine fuelled with tested fuels are presented in Fig. 2a-f below.

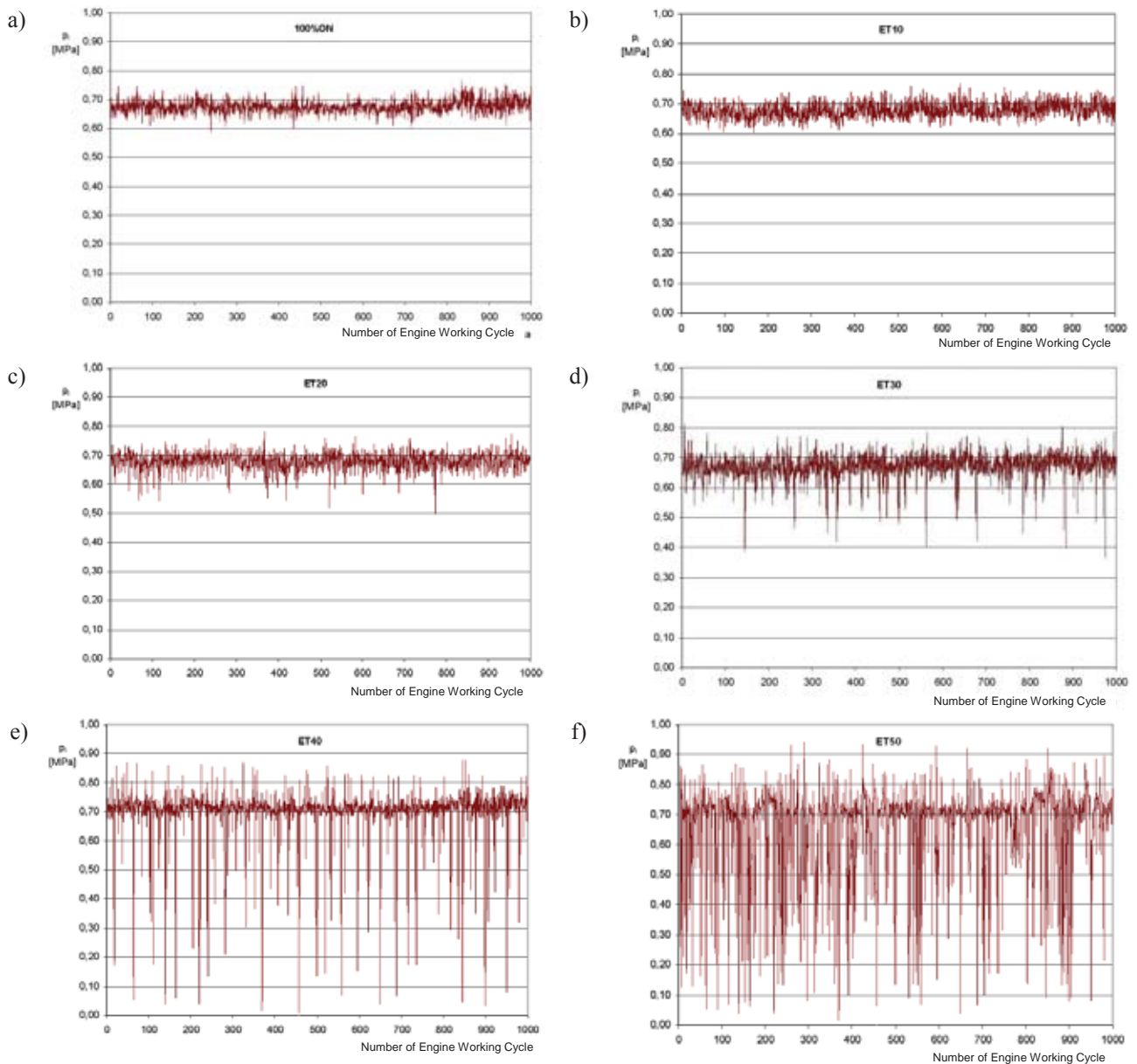


Fig. 2. Values of mean indicated pressure vs. cycle number for AD3.152 engine fuelled with: a) pure diesel oil, b) ET10, c) ET20, d) ET30, e) ET 40, f) ET50

Tested engine fuelled with diesel oil or blends ET10 – ET30 works without any problems with constant values of torque $N=120$ Nm at 1200 rpm. In case of fuel ET40 engine works more and more unstable. Engine fuelled with ET50 works very “hard” and value of torque can not be regulated higher than about 80-100 Nm.

Using formula (1) the values of unrepeatability index of mean indicated pressure have been calculated for all tested fuels. Results are presented in Fig. 3.

The relationships visible in Fig. 2 and 3 show, that only in case of fuels ET10 and ET20 its combustion process occurs without misfiring. Further increasing of ethanol content in diesel oil follows to combustion disturbing.

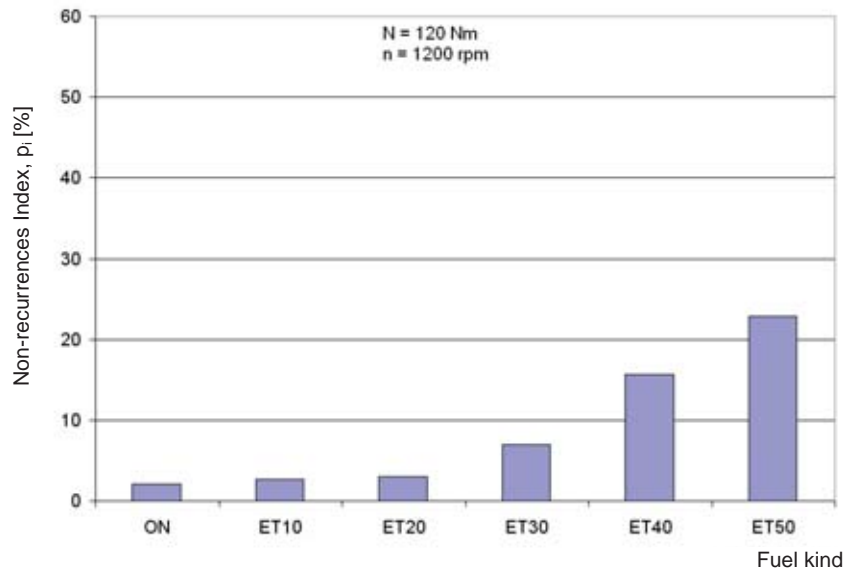


Fig. 3. Variations of unrepeatability index of mean indicated pressure in relationship to kind of tested fuels

5. Conclusions

This paper describes preliminary experiment results, where tested engine was fuelled with blends containing diesel oil, synthetic ethanol and fatty acid methyl esters.

100% pure ethanol can be blended with diesel oil in any proportion but such mixture is clearly, homogeneous and stable above 30 °C only. Below this temperature phase separation is observed [2]. For this reason blends of ethanol and diesel oil should be mixed with using of special emulsifier. There are a lot of different commercial products which using prevent fuels blends against its phase separation. The most available and non expensive emulsifier for tested blends is FAME. Its small addition (about few per cent) improves different properties of fuels mixture. In this research 5% by vol. FAME addition was used.

The objective of this research was focused on studying the misfire phenomenon in relationship to ethanol content in diesel oil. Test results suggest that small quantities of ethanol in mixture of diesel oil and FAME can be used as a fuel for diesel engines. Of course it should be preceded by other tests. This research show that up to 20% by vol. ethanol content in fuel mixture are save because no misfire phenomenon was observed during engine work. In case of mixture ET30 misfire wasn't observed, but analysis of Fig. 3 shows that combustion process isn't so repeatable as for: ON, ET10 or ET20. Using of higher quantity of ethanol in diesel oil follow to engine unstable work caused by misfiring. It was observed for mixture ET40 and especially for ET50. 45% addition of ethanol in diesel oil is to high value for tested engine with relatively low ratio of compression equal 16,5. For comparison, compression ratio in the ethanol bus engine prepared by SCANIA for using ETAMAX D fuel (95% pure ethanol) equal 24 [1]. Research shows that tested engine is not possible to operate with using above 40% of ethanol content in diesel oil, as the fuel simply will not ignite.

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