

AGING PROCESSES OF BIODIESEL AND BIODIESEL/DIESEL FUEL BLENDS

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Abstract

There has been increasing interest in recent years in the use of biodiesel as a substitute for petroleum-based diesel fuel. Fatty acids methyl esters (FAME) in a pure form are applied as a biodiesel B100 or as blends with diesel fuels named as the B10 biodiesel, the B20 biodiesel etc. FAME is susceptible to oxidation and to changes of other essential parameters during aging processes, which have an essential influence the NOx emission. Change of biodiesel parameters results in deterioration of fuel working properties and in increase of the NOx emission level. The increased NOx emission level is accompanied with high viscosity. Experiments with the PDPA laser-equipment showed that high content of biodiesel in a fuel increases the Sauter Mean Diameter (D_{32}) of a fuel spray. The Sauter Mean Diameter increases with time of the aging process of biodiesel, what additionally can unfavourably influence the level of emission of exhaust gases. The research results of samples of aging processes of Rapeseed Methyl Ester (RME) accomplishing requirements of the EN 14214 European Biodiesel Standard, diesel fuel accomplishing requirements of the EN 590 (for based diesel fuel and blends of based diesel fuel and RME containing 1%, 5%, and 20% RME) are presented in the paper.

Determination of influence of the fuel properties and the aging process on the acid number, kinematic viscosity, cloud point, cold filter plugging point, and pour point of fuel samples was an aim of performed research, as well the aging RME effect on elastomers comparatively with fresh RME. The process of fuel samples aging was enforced by the daylight (sun) effect, air, the elevated temperature and water. Fuel samples were aged in laboratory conditions during 15 and 60 weeks. Then the changes of fuels properties with relation to the same properties in initial conditions were determined. The water presence intensifies the process of the RME aging, especially in longer contact. An essential novel aspect of the paper is a relation determined between changes of biodiesel properties during aging and the NOx emission level that is connected mostly with increased viscosity. Rise of viscosity increases size of droplets of sprayed fuel, which results in increased emission level. Prevention of viscosity changes is an efficient way of the NOx emission decrease.

Keywords: diesel engines, biofuels, FAME, fuel aging, emissions

1. Introduction

There has been increasing interest in recent years in the use of biodiesel as a substitute for petroleum-based diesel fuel. Vegetable oil was used as a diesel fuel as early as 1900, when Rudolf Diesel demonstrated that a diesel engine could run on peanut oil. However, its use as a fuel attracted little attention.

Biodiesel is the name for a variety of ester-based oxygenated fuels from renewable biological sources. It can be used in compression-ignition (diesel) engines with little or no modifications.

Pure biodiesel is biodegradable, nontoxic and essentially free of sulphur and aromatics.

Biodiesel is a methyl or ethyl ester of mainly vegetable oils. Biodiesel readily blends with diesel fuel in any percent. The blend level is a function of economics, the desired emissions profile, material compatibility, and combustion characteristics. Methyl or ethyl esters can be produced from vegetable and tree oils, animal fats. These oils are blended with an alcohol (usually methanol, although ethanol can be used as well) and a catalyst such as sodium hydroxide. The resulting chemical reaction which occurs at moderate temperatures and pressures produces an ester and glycerine [1-5].

The compression ignition engine normally has a higher oxides of nitrogen (NOx) emissions profile compared to engines fuelled with other products and. However, this problem is not insurmountable and a number of techniques are being developed to ensure that NOx emissions with biodiesel will be lower than for diesel fuel. Recent research suggests that biodiesel used in new engines developed to meet emission standards will not increase NOx emissions [8-10].

Biodiesel has a number of advantages when compared with both petroleum diesel and other alternative fuels. It needs to be emphasized, however, that the goal of the biodiesel industry is not to replace petro diesel or to supplant the invaluable role of other alternative fuels. Each of these fuels has a place in the development of a balanced energy industry. The compression-ignition engine has certain advantages over spark-ignition engines and role of biodiesel is to contribute to the longevity and cleanliness of diesel engines. The main benefits of biodiesel are increased energy self-sufficiency for importing countries, increased demand for domestic agricultural products, biodegradability and improved air quality, particularly lower sulphur emissions than from fossil fuels. Exhaust emission improvements include substantial reductions in carbon monoxide, hydrocarbons and particulates, although the production of nitrogen gases is similar to regular diesel fuel. Under conditions of increasing demand for diesel, partial substitution of biodiesel for petroleum diesel or blending of the two would help to stabilize the release of greenhouse gases.

Reduced emissions make biodiesel suitable for use in major cities where air pollution is a problem. Also, its lower emissions make biodiesel suitable for use in confined areas such as mines where ventilation is a concern. Pure biodiesel has low aquatic toxicity and is completely biodegradable in about 30 days.

Biodiesel is a fuel applied actually to the feed of compression ignition engines. Most often biodiesel is made methyl esters of fatty acids (FAME), received from vegetable oils, after frying fats and animal fats. In Poland, as biodiesel, methyl esters of the rapeseed oil are applied. (RME). Fatty Acid Methyl Esters (FAME) are widely applied for feeding of compression-ignition (CI) engines. They are applied as the B100 fuel or as the additive for petroleum-based diesel fuels in quantity of 10% (B10) or 20% (B20). FAME demonstrates a small resistance to oxidation, resulting in a small stability during storage and engine operation. This feature is one of FAME disadvantages as the engine fuel. Major cause of the FAME oxidation is presence of double bonds in the structure of particles entering into their composition. Besides intensity of FAME oxidation (aging) depends on storage conditions, presence of air, heat, light, as well as presence of catalytic compounds and oxidation inhibitors [7, 13, 17, 25]. A result of oxidation is deterioration of FAME basic parameters, among other things increase of: Acid Number, viscosity, content of impurities due to creation of gums and deposits, which can cause blocking of pipes and filters in feeding system of an engine.

The FAME oxidation stability may be increased by application of fatty acids with the greater saturation degree but it makes worse their cold flow [13]. So most often the FAME oxidative stability is improved with antioxidative additives [6, 7, 25]. However antioxidative additives only retard process of the FAME oxidation (aging) but do not prevent of its development [16].

The oxidative stability (resistance to aging) of FAME is assigned during laboratory-tests, most often with the Rancimat method (EN 14214 standard) or with the OSI method (Oil Stability Index). The Rancimat method cannot directly measure the overall storage stability of fuels, since other conditions such as presence of water, microbiological contamination and storage conditions

would affect fuel quality during storage. The research [18] showed that relative content of antioxidative additives, resistant to oxidation of ester itself and some content of glycerines in it, indeed influenced the FAME oxidative stability. The influence of metals on the oxidation process is low one. In research results [18] of the resistance on the FAME oxidation stored in closed containers at the temperature equal to 43°C, with fixed space of air are presented. The aging parameters (quantity deposit, acidity, viscosity) did not show essential changes during 4-8 weeks, and then they increased.

Study of the oxidative stability of different samples of biodiesels stored for 30 months in clear and dark glass-containers, in the room temperature are reported in [12]. Slight differences between samples exposed and not exposed to the light during 12 months were noticed. After that time, differences were greater and presence of air and water had the greatest influence aging of samples of biodiesel. Similar results are presented in [17] on the basis research of biodiesel samples and mixtures of biodiesel with diesel fuels [6, 12]. In general, oxidative stability researches are realized for the FAME without improver additives [14, 15].

2. Advantages of biodiesel

Biodiesel is associated with lower engine emissions of HC, CO, and particulates compared to levels associated with diesel fuel. These lower emission levels were likely due primarily to the fact that biodiesel contains about ten percent oxygen by weight, and this oxygen helps to oxidize these combustion products in the cylinder. With neat biodiesel, measurable HC emissions are generally eliminated, while CO is reduced approx. 40 percent from levels found on diesel [19-24].

Particulate emissions are reduced between 25 and 50 percent. In addition, the composition of engine particulate matter (PM) is shifted toward more volatile organic compounds and less carbon soot, creating a more favourable environment for treatment by a diesel oxidation catalyst. The volatile organic compounds in biodiesel exhaust also appear to be easier for an oxidation catalyst to reduce, compared to those in diesel exhaust. But using biodiesel generally tended to increase NOx emissions. Substituting neat biodiesel for diesel fuel, NOx emissions increased by approx 10 percent, although the other engines demonstrated almost no change in NOx emissions. There are no statistically significant increases in NOx emission rates with any of the biodiesel fuel compared to neat diesel fuel. The oxygen in biodiesel may be the cause of the observed NOx increase, but this does not explain the lack of NOx increase in other engines including tested by authors. It is possible that other properties of biodiesel or interaction with characteristics of the fuel injection process and combustion chamber dynamics may cause variation in the expected trend toward higher NOx. More research is needed to fully understand the dependence of NOx emissions on biodiesel and other parameters. Neat biodiesel is generally associated with a loss in engine power of about ten percent for the neat fuel, while with B20 power levels are within two percent of the levels observed on diesel fuel. Transient cycle fuel consumption is approx. 10 percent worse with the neat fuel. With B20, transient cycle fuel consumption is essentially the same as with diesel fuel. The 20 percent biodiesel blend directionally demonstrates many of the same trends observed with neat biodiesel fuel. However, the lower biodiesel content of the blend generally resulted in proportionately smaller changes in exhaust emissions, as compared to neat biodiesel fuel.

Research results demonstrate that benefits can be achieved at steady-state operating conditions through the direct substitution of fuels in advanced diesel engines. Additional reductions in emissions may be possible if engine operating parameters such as injection timing and pressure and EGR levels can be adjusted for a specific fuel. The use of RME leads to a decrease in HC and CO emissions but an increase in NOx and particulate emissions. The particulates consist solely of SOF, which contains very low concentrations of PAH and no sulphate or nitrate, and is considered to be unburnt RME. In addition, the mean particle size, which is very important, is 10 times greater, making the particulates less likely to be inhaled and deposited in the lungs. The biological tests show that RME generally present a lower potential health risk than diesel.

3. Fuel species and research methods

Five species of fuel samples were an object of research:

The commercial methyl ester of the rapeseed oil (RME), met the EN 14214:2004 standard, containing in its own composition anti-oxidative additives and additives improving properties at the low temperature.

Tab. 1. Basic parameters of investigating fuels

Parameter	Units	Requirements for FAME according to EN 14214	RME	HON	OND	Requirements for DF according to EN 590
Cetane Index	–		–	50.0	51.8	min. 46.0
Density at 15°C	kg/m ³	860–900	880	841	832	820–845
Kinematic Viscosity at 40°C	mm ² /s	3.5–5.0	4.50	4.90	2.69	2.0–4.5
Sulphur	mg/kg	max. 10	5.1	21.0	10.0	max. 50
Flash Point	°C	min. 120	176	78	63	min. 55
Copper Strip Corrosion Rating max 3 h at 50°C	Corrosion Degree	max. 1	1	1	1	max. 1
Contaminant Content	mg/kg	max. 24	12	11	14	max. 24
Acid Number	mg KOH/g	max. 0.50	0.30	0.05	0.09	
Distillation: – Recovered at 250°C – Recovered at 350°C – 95 Vol.% Recovery Temperature	% vol. % vol. °C		– 87 N/A	14 92 356	36 98 339	max. 65 min. 85 max. 360
Cloud Point	°C		–5.7	2.7	–12.6	Relative to Climatic Conditions
Cold Filter Plugging Point	°C	Relative to Climatic Conditions	–17	3	–16	
Pour Point	°C		<–36	0	–27	

The commercial diesel fuel of brand (OND) met the EN 590:2004 standard.

Based hydrorefined diesel fuel (HON) which does not contain improver.

The 5% RME and 95% HON mixture, and 20% RME and 80% HON mixture.

Basic parameters of samples of investigated fuels are presented in Tab. 1.

All the samples were subjected of the aging process, which was realized by influence of the solar heat (daylight), and with the presence of water. Investigated samples of fuels were stored in glass-containers of the 2 dm³ capacity, filled in the 75% and 37.5% volumes. The part of samples contained 1% vol. of water. Containers were closed, i.e. the exchange of the air being over the fuel surface in the container did not occur. The half of all samples was kept in the room temperature (20°C -30°C) in presence of the natural solar light (daylight). The second half of samples was set in the closed heat chamber (without solar light) in the 50±3°C temperature. After the outflow 15 and 60 weeks, the containers were opened, and samples of fuels were taken for research of functional parameters:

- Cold Filter Plugging Point (CFPP) according to the EN 116,
- Cloud Point (CP) according to the ISO 3015,
- Pour Point (PP) according to the ISO 3016,

- Kinematics Viscosity at 40°C (KV) according to the ISO 3104,
 - Acid Number (AN) according to the EN 14104,
 - Formed Insolubles (sum of filterable deposits and adherent deposits).
- The schema of the aging processes of fuel samples is presented in the Fig. 1.

4. Research results

The first symptom of the aging process of investigated samples was change of their colour from bright brown, after several weeks of aging, to brown and dark brown after tens of weeks of the aging. The darkest colour of samples demonstrated diesel fuels treated with light. On the bottom and sides of containers, in which the samples of fuels were separately aged during 60 weeks, very small separate organic particles appeared. Intensity and degree of investigated aged fuel samples were estimated by means of change of the value of the kinematic viscosity and the value of Acid Number (AN) (Tab. 2 and 3). During aging, the Acid Number (AN) of all investigated fuel samples was increased with the different increase intensity of the Acid Number. The greatest AN value in fresh conditions demonstrated RME - over 6 times greater than HON and about 3 times greater than OND. The highest absolute AN values in all the aging conditions showed RME, the lowest - HON, and a little higher - OND.

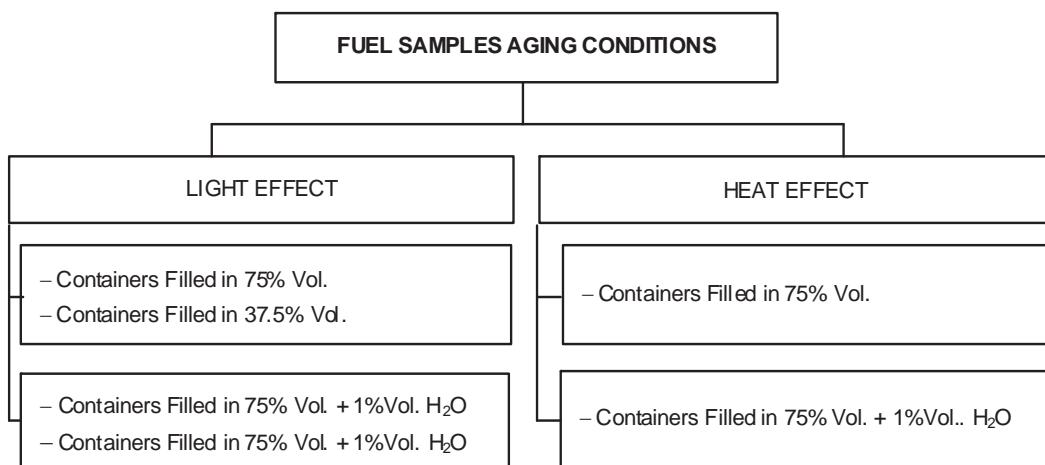


Fig. 1. The aging of fuel samples

The greatest increase of the AN value (the most intensive aging) of RME caused thermal force (aging at the 50°C), and then presence of the greater air presence over the fuel surface. It shows activity efficiency of antioxidative additives in the normal ambient temperature. At the higher temperature, the influence of the antioxidative additions is less efficient. Also the influence of the water presence on the aging process depends on temperature (Fig. 2). The greatest increase of the Acid Number value was observed for RME at the temperature of 50°C at the content of 1% water (Fig. 2), and then at the presence of the greater volume of air over the fuel surface. Hydrocarbon (OND and HON) fuels had the higher increases of the AN value for aged samples, for greater quantity of air over the fuel, and they had lower increases for the thermal treatment. Water presence did not increase the aging intensity of those samples. The AN values for OND and HON were the same as for other aging conditions. The increase of the value of the Acid Number of mixtures RME and HON was the greater the content of RME was greater, for all the aging conditions.

The influence time of aging, (Fig. 3) very essentially affects the intensity of the Acid Number increase. The aging intensity (increase of AN value in time) under temperature conditions of 50°C for commercial RME is the same as for commercial OND but while affecting by greater quantity

of air, presence of light, and at the ambient temperature of about 25°C. However absolute values of the Acid Number as well as its increase for RME are several times greater than for OND and HON. In the first aging period, presence of water does not influence the AN change of the investigated fuels. However for aging time increase, the water presence causes double increase of the Acid Number for RME and only slight increase of the AN for the diesel fuel. The continuous increase of the AN value together with the aging time increase confirms statements reported in (5) that the presence of the antioxidative additive only retards the aging process of RME but does not prevent of its development. The similar behaviour demonstrates OND but changes in aging are very small ones for the fuel.

Investigated samples of fuels characterized by different values of the kinematic viscosity (KV) at the initial state at temperature of 40°C (Tab. 3). RME and HON, and their mixtures had close each other values of KV within the range from 4.50 mm²/s (HON) to 4.90 mm²/s (RME), and OND samples had viscosity about 2 times lower (2.69 mm²/s). As a result, aging processes, slight increase of KV for all investigated samples in all aging types (Tab. 3) followed within the range 1-5%, except of OND samples in which increase of viscosity accomplished 15-27% after 16 weeks aging with reference to samples, which did not contain water. Aged samples in ambient temperature at the greater access of the air (filled containers of 37.5% volume) had the highest viscosity increase. The presence of the water did not have influence the viscosity increase of RME and HON, and their mixtures. Only samples of the commercial diesel fuel (OND) had the greatest increase of the kinematic viscosity after 16 weeks aging without the water presence. However, after 60 weeks of aging, the KV increase was the same as for other samples of fuels, what is difficult for explanation.

Tab. 2. Total Acid Number of the fuel samples for various conditions and time of aging, mg/KOH/g

No.	Aging Conditions	Aging Time (Weeks)	OND	HON	RME	HON	
						+5% RME	+20% RME
1.	Samples in Initial State	0	0.09	0.05	0.30	0.06	0.11
2.	Solar Radiation, Container Fulfil of 37.5%	15	0.15	0.10	0.34	0.23	0.26
		60	0.36	0.14	0.44	0.42	0.51
3.	Solar Radiation, Container Fulfil of 75%	15	0.12	0.09	0.33	0.11	0.13
		60	0.14	0.09	0.49	0.17	0.16
4.	Temperature of 50°C, Container Fulfil of 75%	15	0.10	0.08	0.43	0.07	0.13
		60	0.12	0.18	0.74	0.09	0.22
5.	Solar Radiation, Container Fulfil of 37.5% + 1% H ₂ O	15	0.15	0.09	0.37	0.17	0.21
		60	0.42	0.14	0.69	0.25	0.43
6.	Solar Radiation,, Container Fulfil of 75% + 1% H ₂ O	15	0.11	0.07	0.37	0.08	0.13
		60	0.13	0.07	0.49	0.12	0.16
7.	Temperature of 50°C, Container Fulfil of 75% + 1% H ₂ O	15	0.10	0.06	0.42	0.07	0.12
		60	0.11	0.06	1.09	0.09	0.24

The low viscosity increase of the diesel fuel and RME samples in aging processes at high growth of the Acid Number means that a result of those processes, aging products for both fuels are kind of acids. For lower quantity of aging products, main aging products are kind of resins and other compounds with high molecular mass.

Tab. 3. Kinematics viscosity at 40°C of the fuel samples for various conditions and time of aging, mm²/s

No.	Aging Conditions	Aging Time (Weeks)	OND	HON	RME	HON	
			+5% RME	+20% RME			
1.	Samples in Initial State	0	2.69	4.90	4.50	4.83	4.72
2.	Solar Radiation, Container Fulfil of 37.5%	15	3.45	4.96	4.76	5.01	4.76
		60	2.77	5.16	4.68	5.02	4.97
3.	Solar Radiation, Container Fulfil of 75%	15	3.32	4.94	4.65	4.93	4.67
		60	2.70	5.04	4.65	4.86	4.70
4.	Temperature of 50°C, Container Fulfil of 75%	15	3.12	4.92	4.74	4.88	4.68
		60	2.69	4.96	4.63	4.85	4.74
5.	Solar Radiation, Container Fulfil of 37.5% + 1% H ₂ O	15	2.79	4.99	4.80	4.96	4.81
		60	2.81	5.05	4.75	5.04	4.91
6.	Solar Radiation,, Container Fulfil of 75% + 1% H ₂ O	15	2.76	4.89	4.67	4.90	4.69
		60	2.73	4.95	4.57	4.92	4.79
7.	Temperature of 50°C, Container Fulfil of 75% + 1% H ₂ O	15	2.77	4.93	4.64	4.89	4.65
		60	2.73	5.02	4.59	4.91	4.75

The small quantity of deposits, which are emitted on the bottom and on the sides of containers filled with aged sample of fuels, and very small size of particles forming these deposits confirm this statement. These deposits indicated also the small adhesion to the sides of the containers, in which aging processes were realized. Their quantities in samples of fuels after 60 weeks aging are put in Tab. 4.

Most sediment it was noted down in samples of all investigated fuels which were subject to the operation of oxygen from air, and the solar radiation in the presence of water. In these samples most sediment contained the mixtures of RME and HON. This means the occurrence of effects of the synergy, i.e. the senescence RME is helped a presence of hydrocarbons diesel oil

Such course of aging processes (formation of gums and other compounds with the high molecular mass) causes that the changes of the fuel properties at the low temperature investigated fuels are slight ones. It confirmed research results of: Cold Filter Plugging Point (CFPP), Cloud Point (CP) and Pour Point (PP). Pour Point for all aged samples was the same as for fresh samples (Tab. 1). Pour Point (PP) for RME and HON mixtures carried out -5°C for the 5% RME with HON mixture, and -15°C -18°C for the 20% RME with HON mixture. Cloud Point for all samples did not undergo change for all aging types.

Only aging samples of RME in water presence showed the CP increase from -6°C to +14°C.

Tab. 4. Formed insoluble of the fuel samples for various conditions after 60 weeks of aging, g/m3

No.	Aging Conditions	OND	HON	RME	HON	
					+5% RME	+20% RME
1.	Solar Radiation, Container Fulfil of 37,5%	720	306	30	862	1608
2.	Solar Radiation, Container Fulfil of 75%	58	151	10	271	302
3.	Temperature of 50°C, Container Fulfil of 75%	19	17	10	293	344
4.	Solar Radiation, Container Fulfil of 37,5% + 1% H ₂ O	1400	902	480	1920	1990
5.	Solar Radiation, Container Fulfil of 75% + 1% H ₂ O	120	57	248	261	272
6.	Temperature of 50°C, Container Fulfil 75% + 1% H ₂ O	25	16	17	54	236

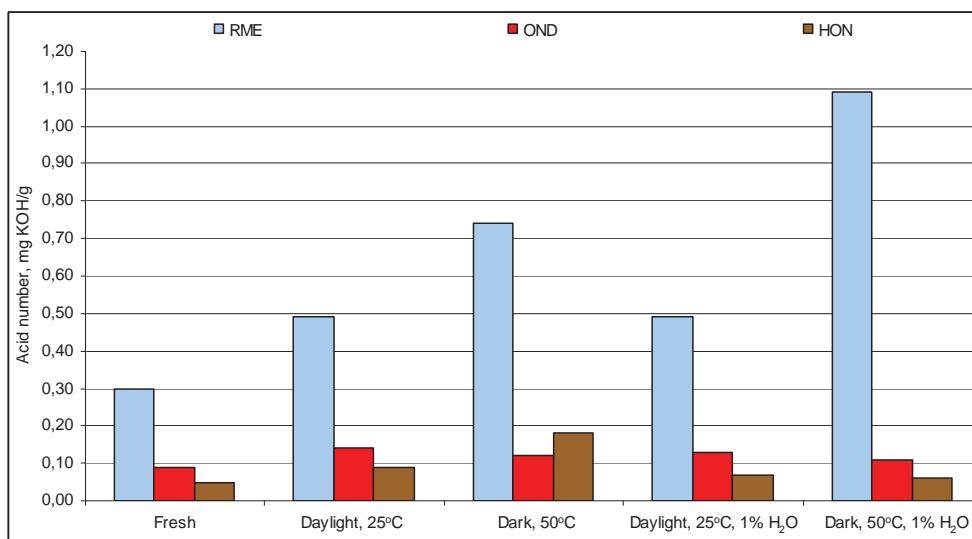


Fig. 2. Acid Number of fuel samples aging at different conditions during 60 weeks, filling glass bottles 75%

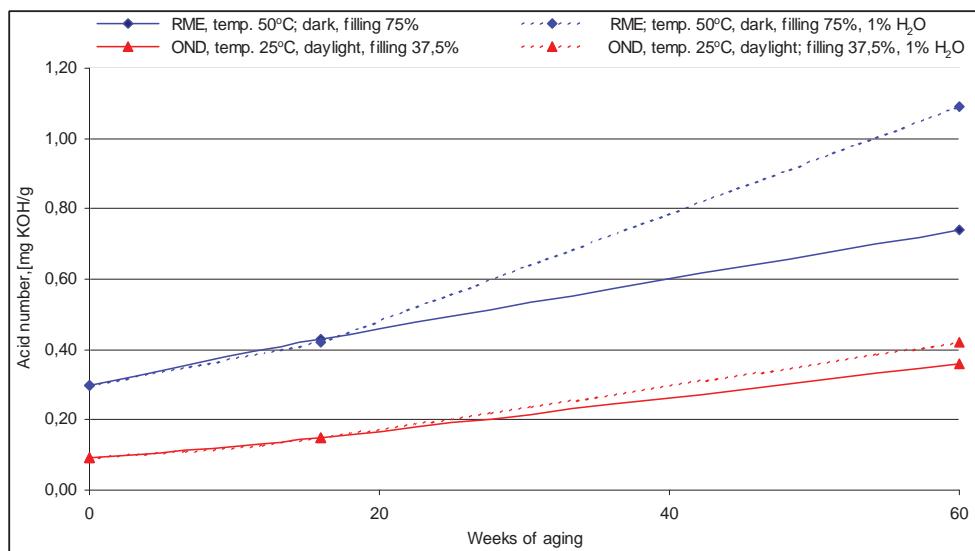


Fig. 3. Acid Number as a function of time and conditions of aging for evaluated samples of fuels

Cold Filter Plugging Point (CFPP) for hydrorefined diesel fuel (HON) after 60 weeks of aging decreased about 2-3°C (Fig. 4) what means improvement of properties at the low temperature of the diesel fuel (HON) for all aging conditions. The similar effect was observed for the commercial diesel fuel OND (containing depressant). However as a result of aging processes of RME (containing depressant), the CFPP value increased 1-2°C, in other words the slight deterioration of properties at low temperature (Cold Flow Properties) was observed (Fig. 4). RME and HON mixtures practically did not change of the Cold Filter Plugging Point (CFPP) - its decrease for HON is compensated by increase for RME.

RME destructively influences some elastomers (seals). Investigation of influence of fuel samples on elastomers performed with butadiene-acrylonitrile (NBR) and epichlorohidryl (ECO) rubbers, and resistant gum on petrol (GBO) confirmed that elastomers from these materials had a greater volume increase and hardness decrease for the RME than for the diesel fuel during the acting of fuels on elastomers in the course of 168 hours (Fig. 5 and 6).

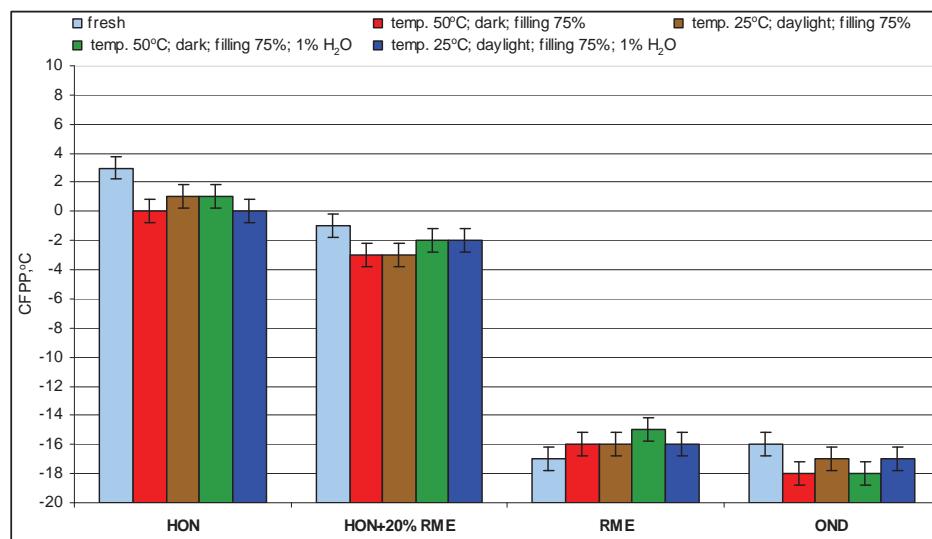


Fig. 4. Cold Filter Plugging Point of fuel samples fresh and aging at different conditions during 60 weeks

All the fuels caused swelling and decrease of hardness for every investigated elastomer. Least changes were caused by the commercial diesel fuel (OND), greater - by base diesel fuel (HON), and greatest - by RME.

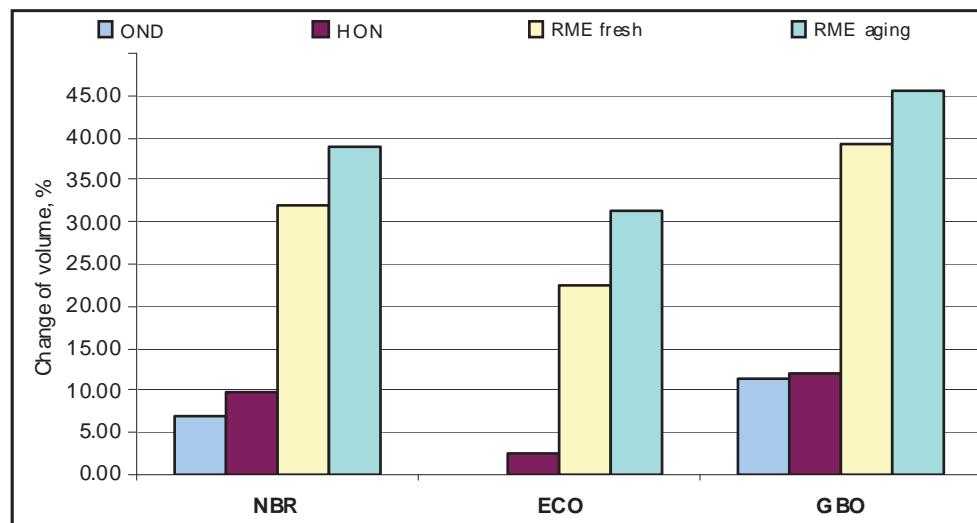


Fig. 5. Relative change of volume of elastomers after 168 h of interaction of various fuels

The destructive effect of RME was several times greater than the effect of diesel fuel, and changes of parameters were so large that all three elastomers were completely not resistant on biodiesel impact. The performed research showed (Fig. 5 and 6) that the aged RME was more active with relation to elastomers than the fresh RME. At slight aging of RME (increase of the Acid Number from 0.30 to 0.46 mg KOH/g) and at the presence of 1% water, increase of the volume of elastomers was greater (5-70%), and decrease of their hardness was also greater (7-25%) with relation to changes due to by fresh RME (with normative parameters).

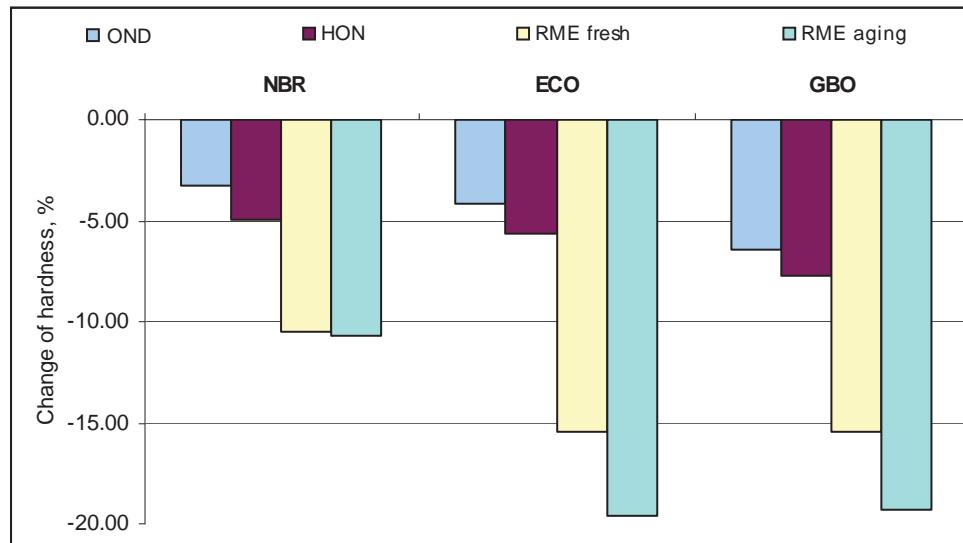


Fig. 6. Relative change of volume of elastomers after 168 h of interaction of various fuels

5. Results of laser research

The knowledge of sizes of droplets and their distribution in fuel spray is relevant in performing experiments of atomized fuel stream in conditions similar to those in diesel engine. In engine conditions, droplets are different depending on conditions of flow and fuel properties. In order to determine sizes of droplets and their distribution at high injection pressures and various fuel values of viscosity, investigation of fuel spray atomization spectrum has been carried out with use of dynamic laser analyzer LDV (Laser Doppler Velocimeter) and PDPA (Phase Doppler Particle Analyzer). The tests results show that the common rail injection systems when it was fed with the lower viscosity fuel form the droplets of smaller diameters than injection systems fed with fuel with the higher viscosity value. As the injection pressure was increased, the smaller droplets were formed by the common rail system as well for fuel with lower and higher viscosity values [6].

PDPA and LDV laser methods make possible on determination of size of droplets, their velocity and the distribution. The researches were performed in conditions reflecting engine conditions. Parameters of the spray include average diameters of the main spray and the ambient spray as well as associated statistical parameters, which get out of the scattering sizes of droplets, such as among other things mostly Sauter Diameter D_{32} and Herdan Diameter D_{43} . The laser researches permitted to designate principle parameters of fuel sprays including sizes of droplets and velocity field. Because the biodiesel parameters differ from the diesel fuel parameters, so biodiesel atomization differs from diesel fuel, especially after aging of fuels when the RME viscosity is greater [11].

Schema of test stand for laser measurement of fuel atomization is presented in Fig. 7.

Photos of laser test stand fragment and screen with test results are presented in Fig. 8.

The laser test results of mean droplet diameters (D_{10} , D_{20} , D_{30} , D_{32} , D_{43}) for three injection pressures of 70, 100 and 130 MPa and for two fuels: diesel fuel (No. 1) and RME (No. 2) are

presented in Fig. 9. Injection system fed with diesel fuel (No. 1) of smaller viscosity, generated droplets of smaller diameters than the RME (No. 2) of higher viscosity.

The Sauter Mean Diameter (SMD), with reference to fuel of bigger viscosity at pressure of 70 MPa was larger by 28%, at 100 MPa more by 8%, and at 130 MPa more by 15%. It has been stated that alongside with the injection pressure increase, the decrease of size of droplets occurred. The Sauter Droplet Diameter (D_{32}) at pressure increase from 70 MPa to 130 MPa was smaller by 47% with reference to the diesel fuel, and by 41 % with reference to the RME.

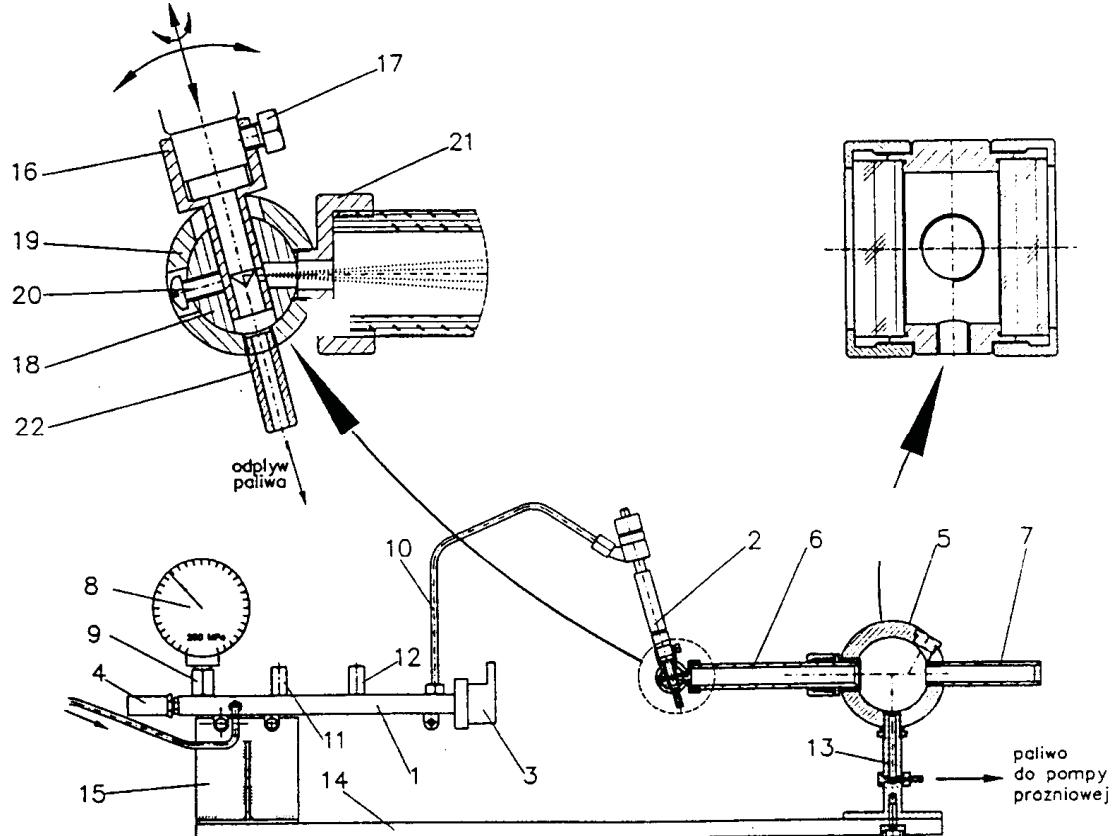


Fig. 7. Test stand of Common Rail system for measurements atomized spray for diesel fuel and RME

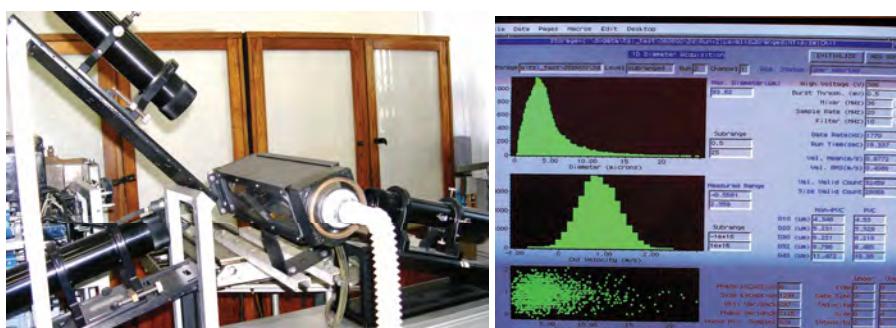


Fig. 8. Photo of laser test stand fragment (left) and screen with test results (right)

The aged fuels have different values of the viscosity, density and surface tension in comparison to the fresh fuels, what exerts an essential influence at additives for fuels having different properties. It causes considerable difference in process of mixture preparation and accompanying it elevated level of NOx emission at the RME feeding. The RME droplet sizes are generally greater than the sizes of diesel fuel. Large droplet size contributes to the increased NOx emission level, what is a characteristic feature for RME as a fuel for diesel engines.

6. Conclusions

In spite of the content of anti-oxidative additives, commercial RME undergoes aging more intensely (under the same conditions) than diesel fuel with such additives. It means that anti-oxidative additives diminish aging process of RME, but do not prevent it. In the aging process of RME, diesel fuels, and blend of RME with diesel fuel mixtures come into being sour and resinous

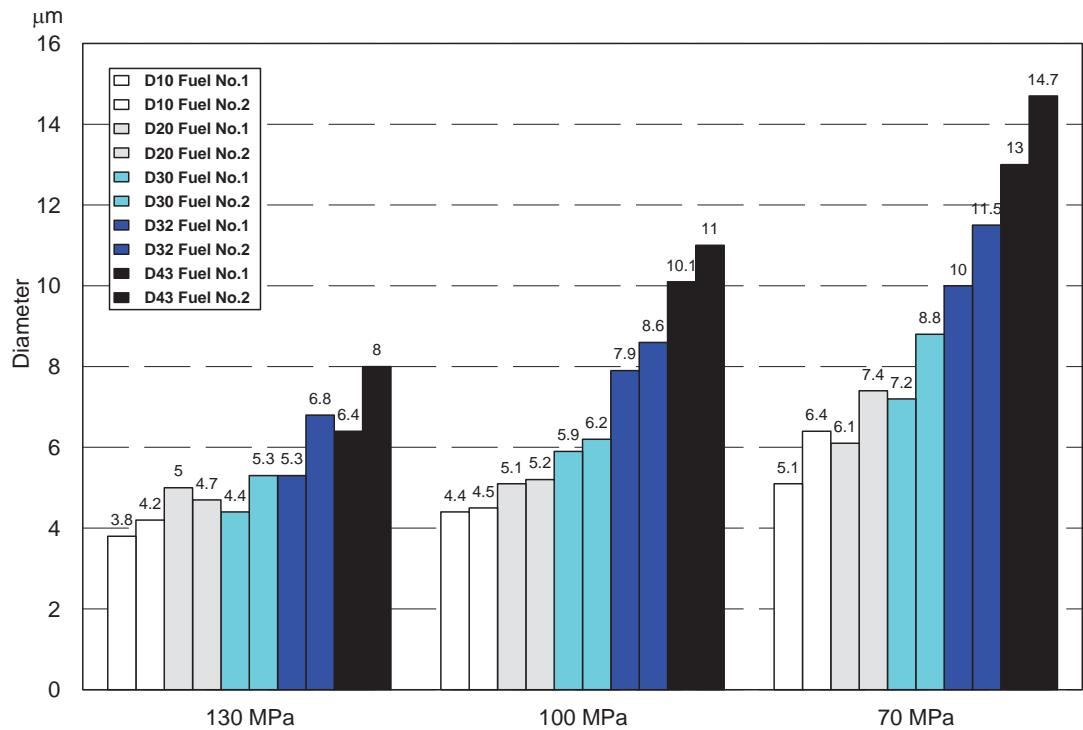


Fig. 9. Mean droplet diameters (D10, D20, D30, D32, D43) for 3 injection pressures 70, 100 and 130 MPa and for two fuels: diesel fuel (No. 1) and RME (No. 2)

compounds. For the RME more sour compounds come into being, what causes the considerable increase of the Acid Number value, greater than the AN increase for the diesel fuels. The most intensive aging of commercial RME is caused by thermal force (elevated temperature), and in the second order contact with air. Diesel fuels behave opposite. The aging of the commercial RME (with antioxidative additives) and its mixtures with the diesel fuels cause also the viscosity increase, what deteriorate the process of fuel atomization and enlarges the level the NOx emission. Most sediment arises in fuels which are mixtures RME and diesel fuel. The presence of the water intensifies the aging process of the RME, especially at long contact time. Most sediments are noted down in fuels which are mixtures RME and diesel fuel. The aged RME is more active in relation to elastomers, i.e. causes their greater swelling and softening than fresh RME. It applies to little resistant elastomers on the RME impact except of the diesel fuels. Prevention of viscosity rise with additives, as well as the viscosity decrease is an efficient way of reducing of the NOx emission level.

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