TESTING OF LUBRICATING PROPERTIES OF MIXTURES OF DIESEL AND RME BIOFUELS WITH THE ADDITION OF LINOLEIC ACID

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Abstract

In connection with the limited resources of fossil fuels and the reduction of emissions and stimulation of agricultural areas, a very important indication is the search for alternative fuels – biofuels. The article presents the results of testing the lubricating properties of selected fuel mixtures. The lubricity of diesel fuel (DF), DF with 7% content of methyl esters of rapeseed oil fatty acids (RME), technical linoleic acid and DF with 7% content of RME and 10% content of technical linoleic acid was tested. The research was carried out on the author's research stand in the amount of 20 dm^3 of mixture. Four parameters were taken into account: mass loss of samples, the footprint area of cooperation, diameter of equivalent wheel and average value of the coefficient of friction. It has been shown that the addition of linoleic acid to diesel fuel containing RME causes a significant increase in the mass loss of the samples and the footprint area of cooperation as well as its diameter of equivalent wheel, during lubrication with such a mixture. As a result of the addition of linoleic acid, no positive results were obtained, as the lubricating properties in this case deteriorated. Therefore, it is justified to continue looking for fuel additives that will eliminate this negative effect.

Keywords: biodiesel; lubricity; linoleic acid; wear testing

1. Introduction

Fossil fuels are sources of resources, and their mass consumption has a significant impact on our environment and society [31]. Ensuring sufficient conventional fossil fuel for internal combustion engines and the associated effects of global warming and other environmental problems arising from the burning of fossil fuels are the two most serious problems of our civilization today [4]. Environmental requirements apply to both engines and the fuels used to power them. The most realistic scenario to reduce air pollution from outdated vehicles is the use of fuels that do not require any changes to the engine systems [29]. The growing awareness of fossil fuel depletion leads to an intensive search for renewable fuels

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[13, 30, 38]. The main areas of fuel development are the following areas: improvement of oil refining technology, search for new additives and use of alternative fuels. The development of alternative fuels from agricultural crops is a great hope for obtaining renewable fuels [27, 34]. In addition to the benefits of obtaining raw material for fuel production, this is an opportunity for rural development. The last decade has seen a stunning increase in the production of renewable fuels for energy purposes, growing at an average rate of 7.8% per annum [14].

Scientists from around the world are trying to find and test suitable alternative fuels. For example in [15] authors present results of the performance and exhaust emissions of hydrogen diesel mixture and biodiesel [23]. Hunicz et al., [14] presents a detailed analysis of combustion and emission characteristics of a single-cylinder compression ignition engine fuelled with diesel, hydrogenated vegetable oil (HVO) and their blend (50/50). In [29] is shown research on the combustion processes, energy and emission parameters of various concentration blends of hydrotreated vegetable oil biofuel and diesel fuel in a diesel engine. Similar research which included numerical studies of emission in dual-fuel diesel engine and properties of diesel pilot dose was shown in work [24]. The research of rheological parameters of vegetable oil in detail was shown in [17]. Another researchers [21] tested the environmental characteristics of diesel fuel containing rapeseed butyl esters. In work [25] authors present studies of the properties of fatty acid methyl esters coming from various sources. Studies on the physicochemical properties of catalyst precursors for the production of DME from ethanol are shown in work [26].

Górska et al. [11] studied selected physicochemical properties of microemulsions and fuel additives (diesel oil). In particular temperature dependent properties such as: flash point (FP) and cold filter plugging point (CFPP) as well as lubricity, friction coefficient, corrosiveness and kinematic viscosity of tested fuels were examined [11]. Studies have shown that the tested microemulsion system is not corrosive, kinematic viscosity meets the requirements of the EN590 standard, and such fuel can be recommended for testing the engine without risk of damage. However, less usefulness of such fuel was found in winter periods, this is a frequently raised issue in relation to alternative bio-diesel fuels.

Knowledge of the tribological properties and condition of the surface layer of friction cooperating materials is extremely important for the durability and reliability of technical objects and allows in the future to develop complex criteria for the selection of materials when designing new products [22, 33, 39]. In addition, the environment in which tribological pairs work is also important, hence the testing of lubricating properties of fuels and fuel additives are an important research direction for the automotive industry. This is particularly important for the combustion engine fuel apparatus and its durability as a whole. You can find a lot of scientific research on the non-conventional drive [3], operating conditions of an internal combustion engine [19, 20, 28] and diagnostic applications in relation to the power supply and load exchange systems in the engine [1, 6, 10]. For example Wasilewski et al., [35] investigated the performance of the S-4003 Ursus C-360 engine in terms of variability of its rotational speed powered by Ekodiesel Ultra D. The proper use of the engine operating parameters according to various agrotechnical conditions is consistent with the concept of sustainable agriculture [35]. Droździel [5], carried out an analysis of the relationship between the conditions of work organization of the vehicle and the parameters of the combustion engine. Wolak et al. [36], analyzed the foaming tendency of engine oils used under excessive urban operating conditions. In turn, Kuranc [18] focused on the ecological aspect of starting properties of a spark ignition combustion engine.

Plant-based fuels have great potential in terms of expectations regarding alternative fuels. The main component of vegetable oils are triglycerides, in which unsaturated esters (especially oleic, linoleic and linolenic acids) and glycerin predominate. The glycerin molecule is connected to three, usually different, fatty acid chains [25], which are made of carbon chains of different length (from 14 to 24 carbon atoms) and a different number of double bonds between carbon atoms [12]. The number of double bonds determines the degree of saturation of fatty acids, i.e. the greater the number of double bonds, the greater the unsaturation [12, 25]. In [9], a correlation between the degree of unsaturation and lubricity was observed. Of the tested fatty acid esters containing from one to three double bonds between carbon atoms, linolenic acid ester (C18:3) proved to be the most effective lubricant improving additive.

Vegetable oils contain (0.1-2.0)% free fatty acids, unbound in glycerol esters, formed as a result of oxidation of carbon chains [32]. Transesterification of vegetable oils is carried out using methanol (ethanol or butanol) and involves the conversion of triglycerides, i.e. alcohol molecules form fatty acid methyl ester molecules of vegetable oils and glycerin with fatty acid residues [32].

In the paper Knothe and Steidley [16] the following sequence of oxygen groups was created to improve the lubricity of COOH>CHO>OH>COOCH3>C=O>C-O-C. Anti-wear additives used in diesel fuels containing polar functional groups (carboxyl group, a hydroxyl group, an ester) to allow the adsorption of such additives on the lubricated surfaces and the creation of the boundary layer [2]. Fatty acids contain a carboxyl functional group – COOH, that means a group according to the above sequence of groups improving the lubricity is the strongest one. The COOCH3 ester group, which determines the lubricating properties of esters, occurs further in the said sequence.

Oleic, linoleic and linolenic acids are the main components of rapeseed oil, and their physicochemical properties determine the use of rapeseed oil as fuel for diesel engines [37]. The article presents the results of tests on the lubricity of diesel oil, diesel oil with 7% content of methyl esters of rapeseed oil methyl esters (RME), technical linoleic acid and diesel oil with 7% content of RME and 10% content of technical linoleic acid.

2. Methodology

The research based on the simultaneous abrading of three samples in the form of cone bearing rollers (diameter Ø = 5 mm) on a rotating flat counter sample in form of a longitudinal bearing race, in conditions of lubrication by lubrication factor at temperature of 333 K, pressure of 29.43 kN and total path of friction approximately 2×104 m [8]. The lubricant, in amounts of 20 dm^3, circulates in a closed circuit, filters and stabilizes the temperature. Lubricity was assessed on the basis of mass loss and the contact surface of the samples, diameter of equivalent wheel as well as the coefficient of friction. The mass loss of samples - summary mass loss of three researched samples in test. The footprint area of cooperation - summary footprint area of cooperation of three researched samples in test. The diameter of an equivalent wheel of samples tested - the diameter of wheel which square is equal to summary footprint area of cooperation of three researched samples in test. The sliding friction coefficient according to the Amontons formula is the ratio of the normal force holding the body in contact (N) to the force pressing the friction surfaces (T), perpendicular to the contact surface of the bodies.

Figure 1 presents the test stand for determining the lubricity and wear resistance of materials, which is described in detail in [7].

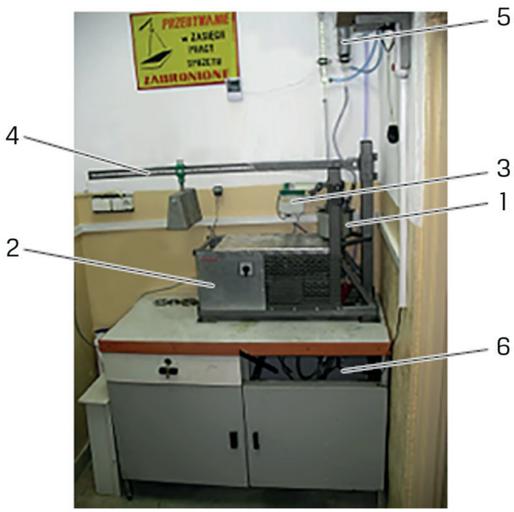

Fig. 1. The test bench to determine lubrication and resistance of materials to wear: 1 – the shield of friction node; 2 – the base and the drive of friction machine; 3 – measuring system of the friction moment; 4 – weighing arm; 5 – temperature stabilization system of the tested lubricant; 6 – circulation system and lubricant filtration [7, 8]

Diesel fuel – Jan (Jan Non-attached Gas Station in Lublin), DF with 7% content of RME Orlen, technical linoleic acid and DF with 7% content of RME and 10% content of technical linoleic acid were tested. In Table 1, are presented the characteristics of diesel fuel and eco diesel fuel.

Tab. 1. Characteristics of diesel fuel ON ORLEN EKODIESEL ULTRA-F and Ekodiesel Ultra D 4.8.

No.	Parameter	Test method	Units	Requirements according to PN-EN 590		Results
				minimum	maximum	
1.	Density at temperature of 15°C	PN-EN ISO 12185:2002 A	kg/m^3	820.0	845.0	831.1
2.	Fractional composition, distils to 250°C	PN-EN ISO 2305:2012 excluding points 9 A	% (V/V)	-	<65	42.1
3.	Fractional composition, distils to 350°C	PN-EN ISO 2305:2012 excluding points 9 A	% (V/V)	85	-	96.2
4.	Fractional composition, 95% (V/V) distils to temperature	PN-EN ISO 2305:2012 excluding points 9 A	°C	-	360	344.6
5.	Cetane index	PN-EN ISO 4264:2010 A	-	46.0	-	52.3
6.	Cold filter plugging point CFPP	PN-EN 116:2015-09	°C	-	-20 S	-26
7.	Cloud temperature	PN-ISO 3015:1997	°C	-	-	-8
8.	Sulfur content	PN-EN ISO 20846:2012 A	mg/kg	-	10.0	6.7
9.	Flash-point	PN-EN ISO 2719:2007 A	°C	>55.0	-	64.0
10.	Water content	PN-EN ISO 12937:2005 A	mg/kg	-	200	51
11.	Viscosity at 40°C	PN-EN ISO 3104:2004 A	mm^2/s	2.000	4.500	2.555
12.	Content of fatty acid methyl esters (FAME)	PN-EN 14078:2014-06 A	% (V/V)	-	7.0	<0.05
13.	Cetane number	STB ISO 5165-2002	-	51.0	-	51.5
14.	The content of polycyclic aromatic hydrocarbons	STB EN 12916- 2011	% (m/m)	-	8.0	1.9
15.	Coking residue (from 10% distillation residue)	STB ISO 10370-2003	% (m/m)	-	0.30	0.01
16.	Ash residue	STB ISO 6245-2003	% (m/m)	-	0.010	0.001
17.	Content of impurities	STB EN 12662-2010	mg/kg	-	24	6.4
18.	Oxidation Resistance	STB ISO 12205- 2003	g/m^3	-	25	8
19.	STB ISO 12156-1-2011	µm	-	460	321	
20.	STB ISO 2160-2003	rating	class 1	class 1		

S – seasonal requirements for the winter period.

A – method accredited by PCA accreditation number AB 387.

3. Test results and analysis

This chapter presents the test results and their analysis, where the lubricity properties of four mixtures were examined. Figures 2-5 show in the form of charts a summary of the results of testing lubricating properties of DF - Jan, DF with 7% content of RME Orlen, technical linoleic acid (LA) and DF with 7% content of RME and 10% content of technical linoleic acid.

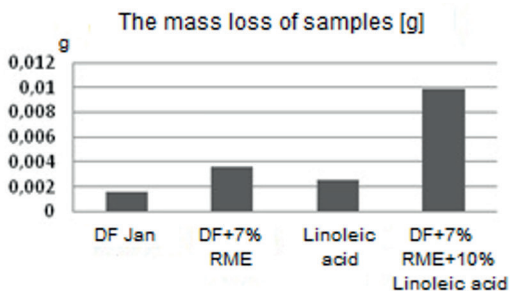

Fig. 2. The mass loss of samples for pure diesel fuel, diesel fuel from RME, linoleic acid and 7% esters 10% acid

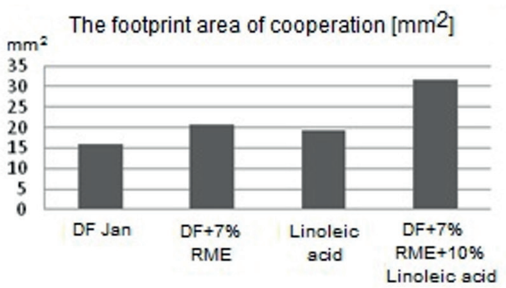

Fig. 3. The footprint area of cooperation for pure diesel fuel, diesel fuel from RME, linoleic acid and 7% esters 10% acid

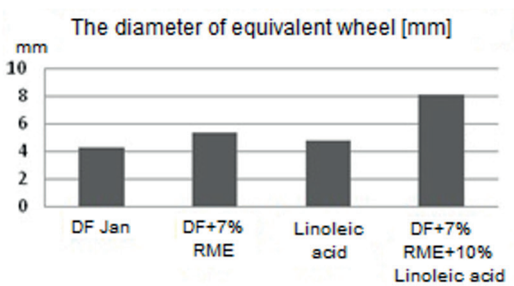

Fig. 4. The diameter of an equivalent wheel of samples tested

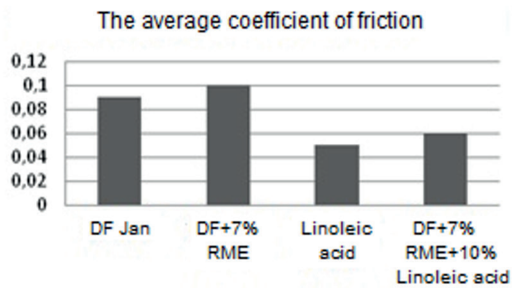

Fig. 5. Average coefficient of friction for the samples tested

Among the tested fuel samples, the best lubricating properties (measured by mass loss, the surface of the trace of cooperation and the diameter of the equivalent wheel) were characterized by diesel fuel. Diesel fuel containing the addition in the form of rapeseed oil fatty acid methyl esters showed a greater mass and surface loss of the samples. The lubricating properties of linoleic acid were found to be intermediate between the lubricating properties of diesel fuel and diesel fuel containing RME. According to the research of Zdziennicka and the team [37], the measured values of the contact angle of linoleic acid on PTFE (polytetrafluoroethylene), PMMA (poly (methyl methacrylate)) and the engine valve show that linoleic acid has the best wetting properties.

The addition of linoleic acid to diesel fuel containing RME caused a significant increase in the mass loss of the samples and the footprint area of cooperation, and also its diameter of an equivalent wheel, when lubricating with such a mixture.

4. Conclusions

The search for alternative fuels is one of the important ways to reduce the consumption of fossil fuels and reduce harmful emissions. In addition, it affects the development of rural areas and the use of selected waste for the production of renewable fuels. In addition to the benefits mentioned, there are also some disadvantages and restrictions to the use of alternative fuels related to, for example, the seasonality of their use. Important technical problems include the impact of the fuel used on the technical condition of the fuel apparatus and the engine itself. Therefore, the paper presents tests of lubricating properties of selected fuels and mixtures at the author's test stand.

In the presented research, an attempt was made to improve the lubricating properties of diesel fuels with the addition of rapeseed oil fatty acid esters, which, according to earlier studies of the authors [7, 8], are clearly worse than for pure diesel fuel. It should be added that the addition of an ester in each studied case increases the wear of samples, so the authors are looking for a way to compensate for this adverse effect. The research sample consisted of the use of linoleic acid in diesel fuel. Unfortunately, no positive results were obtained because the lubricating properties (wear of the samples and the value of the coefficient of friction) in this case deteriorated. As demonstrated in the studies, the addition of linoleic acid to diesel fuel containing RME resulted in a significant increase in the mass loss of the samples and the footprint area of cooperation and at the same time its equivalent diameter, during lubricated with this mixture.

5. Nomenclature

CFPP	cold filter plugging point
DF	diesel fuel
FAME	fatty acid methyl esters
FP	flash point
LA	linoleic acid
PMMA	poly(methyl methacrylate)
PTFE	polytetrafluoroethylene
RME	rapeseed oil methyl esters

6. References

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