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Estimation of selected tribological properties of diesel fuel containing biocomponents

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ABSTRACT

Purpose: The aim of this paper is to present differences of friction process occurred in research carried out on tribological apparatus with diesel fuel and biocomponent additives. The analysis of coefficient of friction and electrical resistance of kinematic pair took place. It was done for kinematic pair worked in pure diesel fuel and biofuel as a diesel fuel with fatty acid methyl ester (FAME) additives.

Design/methodology/approach: The research were conducted on HFRR apparatus (dedicated for lubricity assessment of diesel fuel) and tribotester TR-2. The research were carried out with pure diesel fuel and diesel fuel with 5% and 10% (v/v) content of FAME.

Findings: The results of the research indicate that on account of different construction of apparatus, the friction process assess on the basis of coefficient of friction and resistance is not identical. The FAME additive causes increase of resistance that is over the measuring range of HFRR apparatus. The fact leads to conclusion that standard assessment of lubricity should be replenish by additional analysis of coefficient of friction and kinematic pair resistance.

Research limitations/implications: The research was conducted only for diesel fuel and mixtures of the fuel and FAME. Other fuels were not taken into account.

Practical implications: The presented results can be used as a value directions in research development of fuels and biofuels properties.

Originality/value: The standard research of fuel lubricity boils down to determine wear diameter. This paper indicates other, non-standard approach by additional parameters analysis as coefficient of friction and kinematic pair resistance that was done on tribometer TR-2.

Keywords: Friction; Lubricity; Mineral fuel; Biocomponents

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PROPERTIES

1. Introduction

The lubricity testing of liquid fuel takes place in many research centres all over the world. The specialists literature covers a lot of publications regarding research work under progress within this scope [1-6]. According to available information, neither of existing at the moment standard test methods does reflect the actual conditions prevailing in fuel in system equipment such as fuel pumps and injectors. Moreover, it was impossible to determine the correlation between the test results obtained using different test methods. Still there is no information on research work confirming that criteria taken for mineral fuel are as suitably reasonable as for the same fuel containing biocomponents.

Currently various additives are added to mineral fuels. They also include biocomponents. The importance of biocomponents is highlighted mostly on account of such aspects as ecology (environment protection), economy (increase and big fluctuations of crude oil price), public matters (demand's increase for agricultural raw materials resulting in development of agriculture and rural regions), and energy safety (intention to gain energy independence of countries rich in crude oil) [7-11]. One of major merits supporting the use of biocomponents and biofuels in different fields of transportation is possibility to limit CO_2 emission.

Diesel fuel, acc. to specification PN-EN 590, used commonly in automotive industry as compression ignition (CI) engines fuel can contain FAME - Fatty Acid Methyl Esters (I-st generation biocomponent) up to 7 % (vol.). There was also conducted research work with this biocomponent as a fuel component in the area of power for different type of engine, ie. a turbine aircraft engine. It was revealed that there isn't possibility of use biocomponent FAME type in the aviation industry, however the authors pointed to the application possibilities of this biocomponent in the power supply of turbine engines in other transport sectors [12].

In case of diesel fuel lubricity assessment, many of test methods were developed as a result of many research works. The most known among them are: HFRR (High Frequency Reciprocating Rig), and SLBOCLE (Scuffing Load Ball on Cylinder Lubricity Evaluator). The HFRR is more popular. This test method is described in standard test method [13]. In case of testing using HFRR, the measure of lubricity is corrected wear scar diameter.

This publication presents instead of values of friction couple wear other parameters showing the friction process in medium such as diesel fuel and diesel fuel containing FAME obtained during tests using the following equipment:

- HFRR , according to standard-test method,
- tribometer TR-2.

As a matter of another construction of Tribotester TR-2 friction pair, the paper covers a comparison of the following parameters: friction coefficient and resistance of friction couple depending on test duration. The parameters were recorded on both testing rigs.

2. Testing methodology

The tribological characteristics of fuel were assessed using diesel fuel testing rigs - HFRR and Tribometer TR-2.

The lubricity testing using HFRR regards mostly the fuels for CI engines. The diagram of such apparatus is illustrated in Fig. 1.

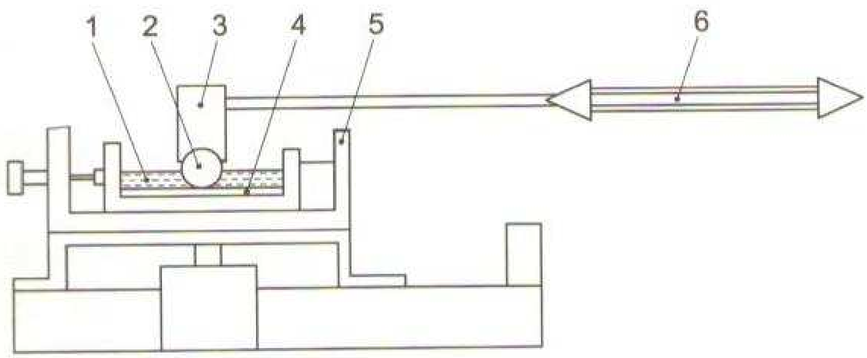

Fig. 1. HFRR diagram [13]: 1- Fluid container, 2- Test ball, 3- Load, 4- Test disc, 5- Heating block, 6- Vibrator

The fuel sample in test container is maintained at specific test temperature. The steel ball is stationary held in vertical chuck and is pressed down against horizontal fixed steel test disc with applied load. The ball is moved reciprocally on metal disc at specified frequency and stroke. The properties of ball and disc, as well as temperature, load and stroke are stated precisely in test method. The ambient conditions, ie. temperature and humidity, enable to adjust the size of wear scar on test ball to standard conditions of environment. As for the results presented in this paper, conditions of testing are the following:

- Test duration – 75 min.
- Vibration frequency of upper ball – 50 Hz
- The ball stroke on lower disc – 1mm
- Initial fuel sample temperature – 60 ^{0}C
- Load – 200 g.

As a result of HFRR tests we have got the resistance of contact and friction coefficient vs time. The same parameters were recorded during tests using the tribometer TR-2. The diagram of TR-2 is illustrated in Fig. 2.

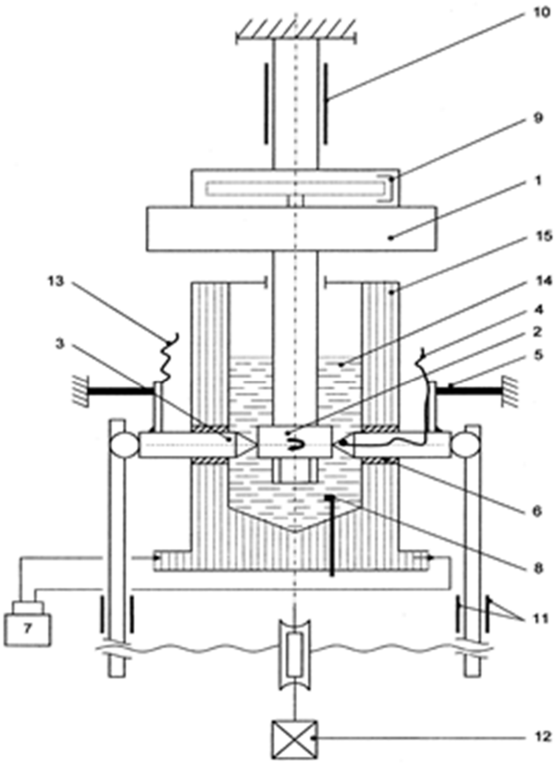

Fig. 2. Tribometer TR-2: 1 – electric engine; 2 – rotary specimen; 3 – counterspecimen with an holder; 4 – thermocouple; 5 – movements sensor; 6 – insulating sleeve; 7 – ultrathermostat; 8 – thetmocouple; 9 – rotational speed sensor; 10 – tensometric sensor of friction force; 11 – load sensors; 12 – stepper motor to load changes; 13 – wires to resistance measurement;14 – lubricant; 15 – liquid in thermostatic circuit.

The tribometer TR-2 is friction machine that because of inventive solutions, is protected by several international patents [14, 15]. The TR-2 is equipped with measurement lines, so it’s completely adapted to conduct professional research of slide friction pairs. The tribotester TR-2 enable changing such parameters of research as: sliding speed, temperature and unit pressure. The friction pair (joint) consists of steel rotary specimen with two, also steel, counter-specimen of 1 mm^2 friction area that are pressed against the rotary specimen.

In case of experiments with fuels conducted using this friction machine, it was tried to make testing conditions as close as possible to the ones during testing using HFRR. Nevertheless, because of friction pair configuration, ie significant differences between friction areas and type of friction pairs movement, it wasn’t fully possible.

The other conditions of test were the following:

1. fuel temperature - 60°C
2. advance speed – 1m/s
3. force – 2 MPa (corresponding to weight of 200 g)
4. test duration – 3000 s.

The parameters such as friction coefficient, contact resistance and oil film thickness were recorded using relevant measurement modules.

The aim of the research was to compare the results describing friction process taking place in different friction pairs (joints) in fuel environment.

3. Results

The tribological research was done on three samples of fuels: diesel without additive of fatty acid methyl esters (FAME), diesel with 5% (v/v) FAME additive and diesel with 10% (v/v) FAME additive. Results of the research were presented on Fig. 3 - 8. The charts show changes of friction coefficient and electrical resistance as a result of FAME appliance. It also give possibility to notice the differences of research results for two various research methods.

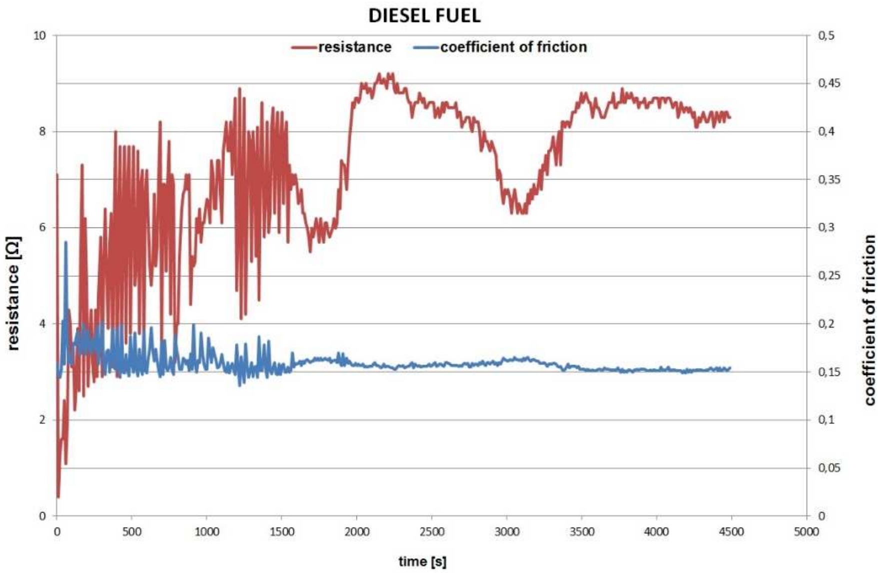

Fig. 3. Changes of friction coefficient and kinetic pair resistance during research on HFRR for diesel fuel. Load p= 0.2 kg, temperature T = 60°C .

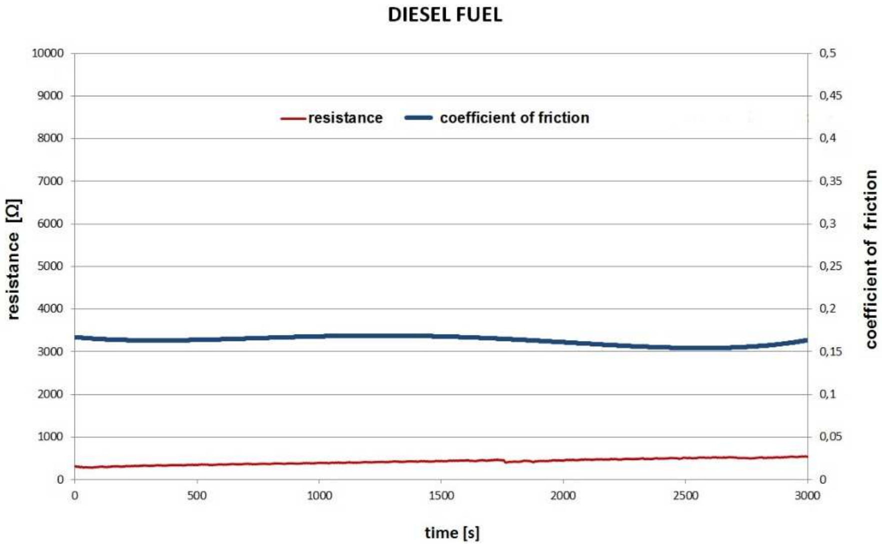

Fig. 4. Changes of friction coefficient and kinetic pair resistance during research on TR-2 tribometer for diesel fuel. Load p= 0.2 kg, temperature T = 60°C

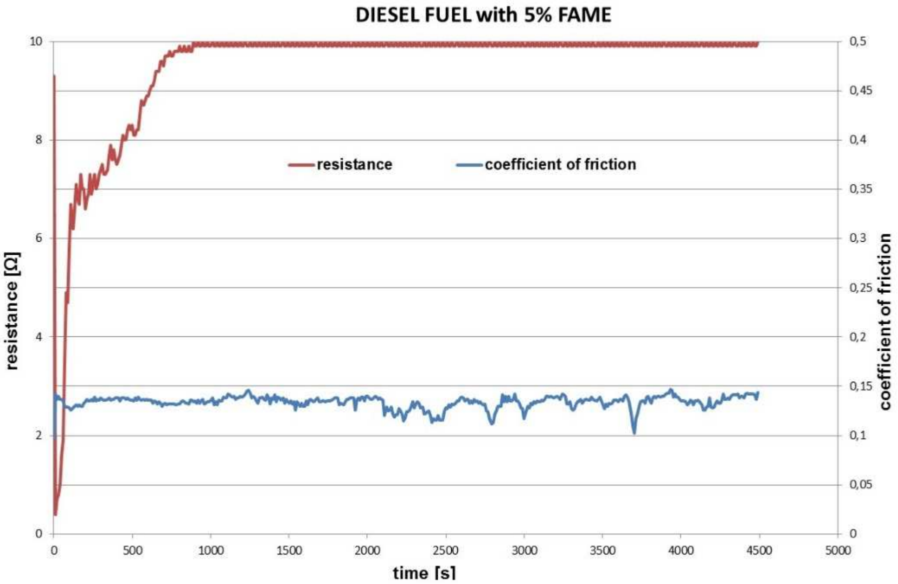

Fig. 5. Changes of friction coefficient and kinetic pair resistance during research on HFRR apparatus for diesel fuel with 5% FAME. Load p= 0.2 kg, temperature T = 60°C

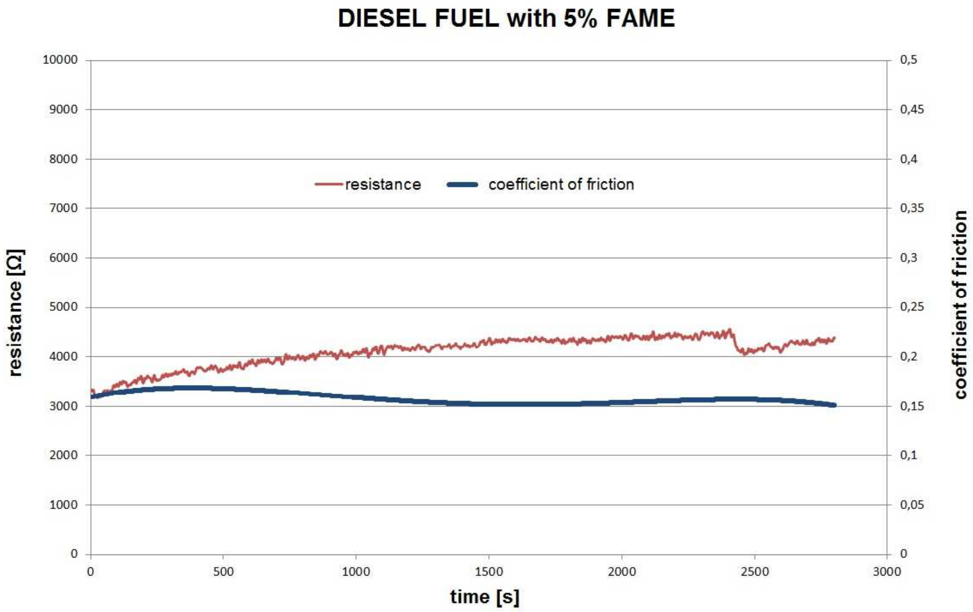

Fig. 6. Changes of friction coefficient and kinetic pair resistance during research on TR-2 tribometer for diesel fuel with 5% FAME. Load p= 0.2 kg, temperature T = 60°C

Taking into account the results presented on figures above there is noticed that more quantity of FAME (Fig. 5, 6) caused higher coefficient of friction than the same for pure diesel fuel (Figs. 3, 4). The value of friction coefficient for diesel fuel and diesel fuel with additive of 5% FAME amounts 0.15 – 0.17. When the FAME reached 10% of fuel content, the coefficient of friction grew up to 0.17 – 0.19.

This situation can be connected with higher viscosity of fuel when the FAME was put in.

Significant influence of FAME is noticeable on changes of kinetic pair resistance. The resistance for pure diesel fuel oscillated in environs of 350 Ω and it was rising during the research to 500 Ω.

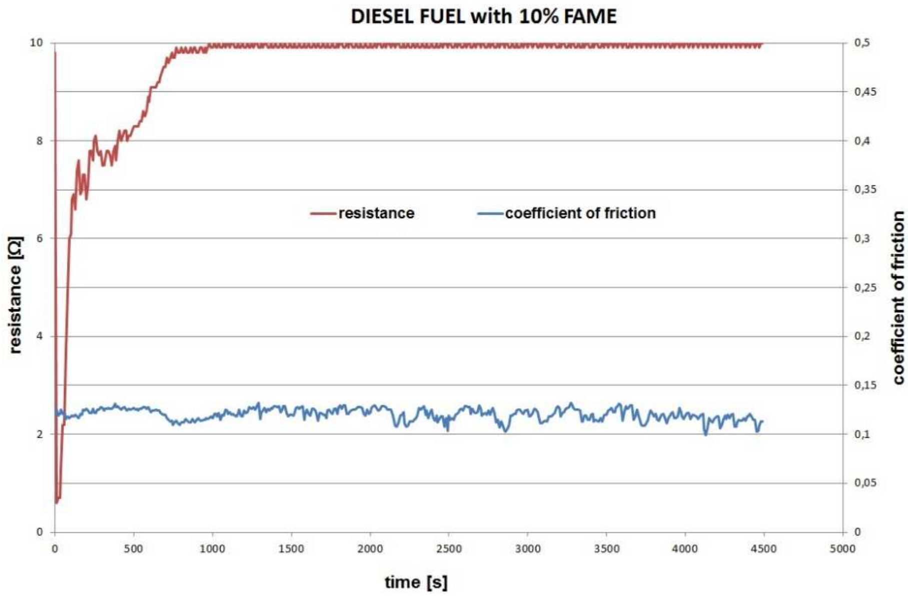

Fig. 7. Changes of friction coefficient and kinetic pair resistance during research on HFRR apparatus with diesel fuel for 10% FAME. Load p= 0,2 kg, temperature T = 60°C

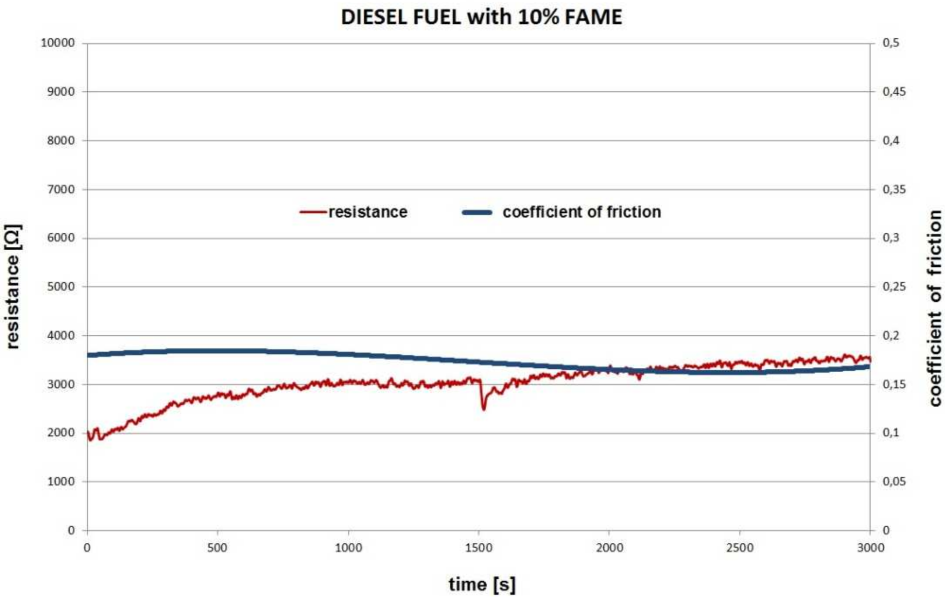

Fig. 8. Changes of friction coefficient and kinetic pair resistance during research on TR-2 tribometer for diesel fuel with 10% FAME. Load p= 0,2 kg, temperature T = 60°C

In the case of experiments with FAME additive, the electrical resistance was decidedly higher. For diesel fuel with 5% FAME, it was amounting 3000 Ω at the beginning of research and was rising with duration of the experiment to 4500 Ω. The resistance of kinetic pair lubricated of fuel with 10% FAME was lower than resistance for fuel with 5% FAME. The difference was about 1000 Ω for the whole research (Fig. 6, 8). The electrical resistance behaviour shows that additives can improve or worse electrical conductivity and fuel film thickness, but the two parameters can be independent from each other, what is shown on Figs. 4, 6 and 8.

The significant differences in resistance results of friction pairs can be noticed on Figs. 3, 5, 7 and Figs. 4, 6, 8. The Figs. 3, 5, 7 shows results of research done on HFRR apparatus, whose construction of friction pair is quite different than TR-2 tribometer pair. In spite of the same load and temperature, the unit pressure in HFRR is decidedly higher because of point contact of samples. Therefore, research on HFRR apparatus characterise lower resistance and fuel film thickness.

However, FAME additive causes that electrical resistance of fuel layer which take part in friction, is higher than the same without FAME in research conducted on two devices. One may notice that in case of HFRR and research on fuel with FAME additive value of resistance exceed measurement range of the apparatus (Figs. 5, 7).

For this device, values of friction coefficient are also different than the obtained on TR-2. The coefficient of friction is the highest for pure diesel fuel (0.16 – 0.20) and the lowest for fuel with 10% FAME additive (0.1 – 0.13).

In spite of similarities in course of friction forces for both methods, significant differences can be noticed. The electrical resistance can have relationship with fuel film thickness, but also with conductivity of the layer, what can be depended on different work conditions and charges generated during friction.

Take into account the relations between resistance and friction coefficient on TR-2 tribometer (Figs. 6, 8), it is visible that the resistance rises up when the coefficient of friction goes down. This phenomena is not observed on HFRR apparatus.

4. Conclusions

The research presented above in the article and conducted on two tribological apparatus: HFRR and TR-2, allow to formulate following conclusions:

On account of different construction of kinetic pairs, the friction process and the courses of friction coeficient and resistance are not the same for TR-2 and HRFF apparatus.

FAME additive in diesel fuel causes the increase of resistance compares it to pure diesel fuel.

The normalize method of fuels lubricity conducted on HFRR device should not be applied for fuels with additives. The reason is the measurement range of resistance that is unsuitable for mixtures differ from pure diesel fuel.

Besides wear value, the assessment of fuels lubricity should contains other parameters as coefficient of friction and resistance of contact point.

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