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INITIAL RESEARCH OF THE EFFECT OF FAME CONTAINING PETROLEUM FUEL BLENDS STORAGE ON LUBRICITY

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Abstract

This paper describes the effect of fatty acid methyl esters (FAME) content in aviation fuels and diesel fuels on lubricity of such fuel blends. Standard petroleum fuels being currently in use contain various components, including the very important ones such as FAME and biohydrocarbons. The latter ones have been used also in aviation turbine fuels. Such use is, among others, associated with limiting of harmful combustion products emission. Lubricity, as one of important parameters related to fuel, directly effects on drive units use. Insufficient fuel lubricity effects probably on extended wear or injection system failure resulting in deterioration of combustion process, emission increase, and engine itself failure. Lubricity study included in this paper was carried out basing on standard test methods with HFRR and BOCLE. The paper describes the nature of lubricity change in relation to prepared fuel blends depending on FAME volume content, as well as the initial storage effect on test results.

Keywords: *mineral fuels, biocomponents, lubricity, storage*

1. Introduction

The explicit definition of term ”lubricity” doesn't exist at the moment. In general, we can say that lubricity is the lubricant property describing its behaviour at boundary friction conditions. The lubricity means the ability to generate the durable boundary layer as a result of adsorption (chemisorption) on solids (base). This ability varies depending on type of solid being in contact with lubricant. The boundary layer durability can be determined indirectly basing on assessment of wear phenomena evaluated using such parameters as wear scar diameter, weight or estimation of the friction coefficient or other criteria [4].

Lubricity problem due to fuel use have appeared at first in 60s of XX century in relation to aviation engine injection system components failure. Later, during war in Vietnam, users of aircraft powered with turbine engine have faced similar problems caused by the fuel quality. The work focused on working out the laboratory test method for aviation fuel lubricity has been started then [6].

The problem of insufficient lubricity of diesel fuel have appeared at the turn of 80s and 90s of XX century (first in the United States, and then in Sweden). The problem has been caused indirectly by ecological action directed towards restriction of harmful emission from vehicles. Such action covers, among others, strives to lower the content of sulphur and aromatics (mostly the cyclic (1- and 3-) ones in diesel fuel. The hydrotreating process, used commonly by refinery industry to remove sulphur compounds from diesel fuel also removes naturally existing compounds that give appropriate lubricity of the fuel. So the lubricity lowering is the negative result of such action. Such diesel fuel can cause premature injection system of CI engines, esp. injection pumps [6].

Currently various additives are added to mineral fuels. They also include biocomponents. The properties of biocomponent added to mineral fuels have to be close to properties of this fuel. Therefore such additives as bioethanol and ETBE can be added to gasolines, inc. the aviation ones, and FAME (fatty acid methyl esters) and biohydrocarbons can be added to diesel fuels and aviation turbine ones. In relation to aviation needs, biohydrocarbons are especially important [3]. Diesel fuel, acc. to specification PN-EN 590, used commonly in automotive industry as CI engines fuel can contain FAME up to 7 % (vol.).

The Air Force Institute of Technology has taken in 2007-2009 the research program to investigate usefulness of FAME biocomponent as component of aviation turbine fuel. Basing on test results it’s found that use of I generation biocomponent - FAME as component of aviation fuel for aviation turbine engines is limited [2]. However, there is no any reason to restrict the application of this biocomponent in fuel used in turbine engines other than aviation ones.

There are many research centres all over the world that carry out lubricity testing. There are many publications related to lubricity research work currently being performed. According to accessible information, we can say that no currently existing standard test method allows lubricity estimation for every case of fuel/additive combination. Moreover, it was impossible to get the correlation between test results from different test methods. Also there are no experiments confirming that criteria for petroleum fuels are appropriately reliable for fuels with biocomponents. Quite the opposite - there are reasons to suppose that methods performing well in case of petroleum fuels are not reliable in case of fuels with modified composition. Use of the FAME could be such an example. Laboratory test results indicate considerable lubricity improvement with biocomponent adding, and, at the same time injection equipment failure cases have appeared, that could be connected with new components in fuel.

Additional the most frequent factor influencing on characteristics, both standard and operation ones, is long-term storage where fuel is exposed to many external conditions such as: temperature (in principle its change), humidity, contamination, pressure, catalytic effect of contaminants and construction materials, and the like. But, the core factor is time. A number of internal reactions resulting in change of fuel characteristics take place during storage. Due to variety of forcing factors some phenomena can be unpredictable. The most frequent result of storage is fuel parameters deterioration, but this direction of changes doesn’t have to prevail in every case. Moreover, the nature and intensity of changes can vary in time.

The paper describes the effect of FAME biocomponent additive, added to Jet A-1 fuel and diesel fuel on lubricity of resulting blends. The lubricity was determined according to standard test methods with BOCLE and HFRR test rigs, basing on wear scar size. The effect of FAME added to mineral fuels and resulting changes in lubricity of fuel blends were tested at the preliminary stage of storage.

2. Test methodology

Lubricity evaluation was carried out for in-house fuel blends prepared by laboratory personnel. The blends include aviation fuel Jet A-1 and diesel fuel (DF) (without biocomponent) as the base, and FAME as the additive. All samples of base components met standard requirements regarding selected physical and chemical parameters: density, kinematic viscosity at specific temperature, and water content (see Tab. 1).

The test fuel blends contained various concentration of specific components. To determine the initial lubricity, the following blends od Jet A-1 and diesel fuel with 2, 5, 7, 10, 15, 20, 30 and 50 % (vol.) FAME were prepared. Research work covering 6-month storage was performed for two types of blend using several selected FAME concentrations: 5, 10 and 20 % in mineral fuel.

The first one (Type I) was created to determine initial lubricity. The blends then underwent the process of laboratory storage in opaque bottles. So, the storage process covered base components mixed together. Another blends (Type II) were created using separate base components, and mixed then before laboratory lubricity testing. Such blends were created just before test in all cases. The reason for such way of sample preparation was information from storage facilities that different processes took place in final fuel blends and base fuels during storage.

Lubricity was tested at laboratory of Division Fuels and Lubricants of AFIT, using common standard test methods for lubricity evaluation of petroleum fuels. According to standard requirements, aviation fuel Jet A-1 lubricity is determined using device BOCLE (Ball-on-Cylinder Lubricity Evaluator) [1], and, in case of diesel fuel, this property is determined using HFRR - High Frequency Reciprocating Rig [5]. The measure of lubricity, acc. to above standard test methods, is wear scar diameter.

Tab. 1. Selected properties of base component samples

Pos.	**Property**	**FUEL**					
		Jet A-1		**Diesel Fuel (DF)**		**FAME**	
		Result	Requirement	Result	Requirement	Result	Requirement
1	Density at 15 ^{o}C, *kg/m^3*	801,4	775,0 to 840,0	837,5	od 820,0 do 845,0	883,1	860 to 900
2a	Kinematic viscosity at -20 ^{o}C, *mm^2/s*	4,154	max. 8,000	X	X	X	X
2b	Kinematic viscosity at 40 ^{o}C, *mm^2/s*	X	X	2,94	2,00 to 4,50	4.483	3,50 to 5,00
3	Water content, *mg/kg*	43,1	X	110,6	max.. 200	249,4	max.. 500

3. Potential direction of fuel blends lubricity change during extended storage time

Chapter 4 shows results of initial testing regarding the effect of storage time (appr. 6 months) of mineral fuels and FAME mixtures on lubricity. Results regarding the effect of extended storage time on lubricity will be published later, after the next testing.

Following, we can see an attempt to estimate potential direction of lubricity change of mineral fuel with FAME during extended storage time. In order to accomplish this goal, selected fuel blends were submitted to accelerate ageing. Prepared blends (Type II) of diesel fuel with 0 % and 20 % FAME content were put into transparent bottles and exposed to daylight for 20 days. At this time, at 5-days interval the HFRR lubricity of these blends was estimated.

According to Fig. 1, it can be seen that in case of neat diesel fuel (without FAME) there is tendency to wear scar diameter reduction during accelerated ageing. In case of mixture containing 20 % FAME there is no such clear tendency. So, we can expect that during extended storage of test blends lubricity change would be noticed for fuels with low FAME concentration (including neat fuels without FAME). Such changes can go towards reduction the wear scar. But the fear of turning such tendency due to chemical changes in fuel during extended storage.

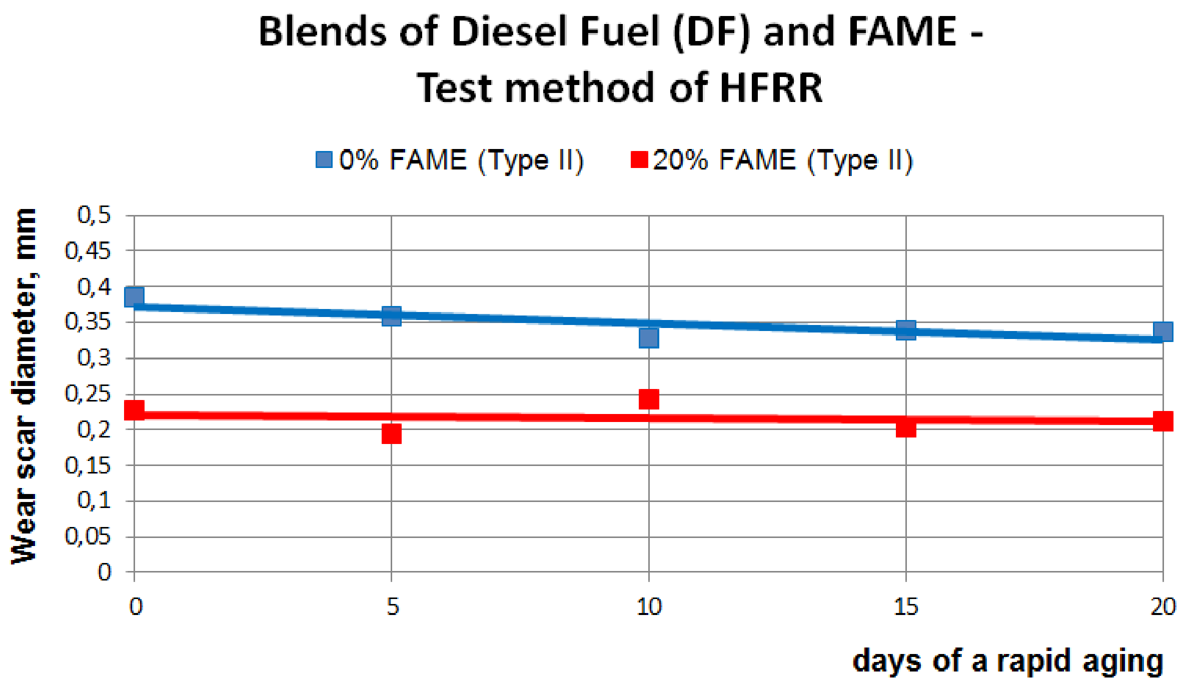


Fig. 1. Lubricity of selected diesel fuel and FAME mixtures during accelerated ageing

4. Lubricity of blends at initial storage period

The effect of storage period (appr. 6 months) on lubricity of fuel blends containing FAME is shown in Figures 2 to 5. The description „0, 1, 2 and 3" on X-axis relate to test numbers. A description „0" means results of initial lubricity testing that are used as reference in case of lubricity evaluation during storage. Consecutive numbers mean lubricity tests performed one by one at specific time intervals. Such interval was in the range of 1,5 to 2 months.

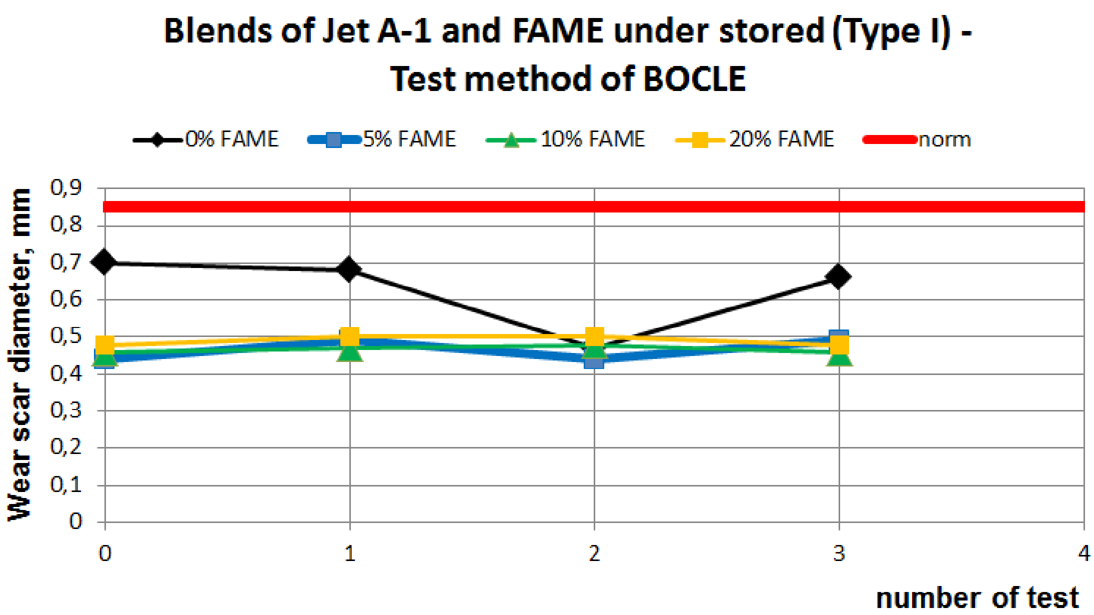


Fig. 2 Lubricity of aviation fuel and FAME blends (Type I) during storage

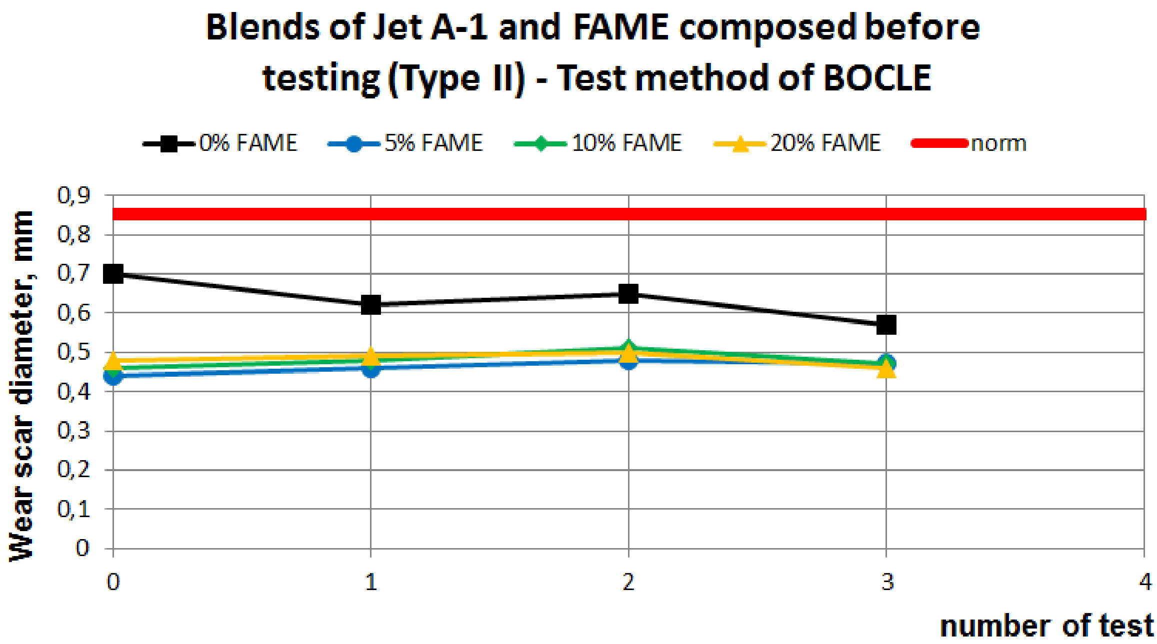


Fig. 3 Lubricity of aviation fuel and FAME blends (Type II) during storage

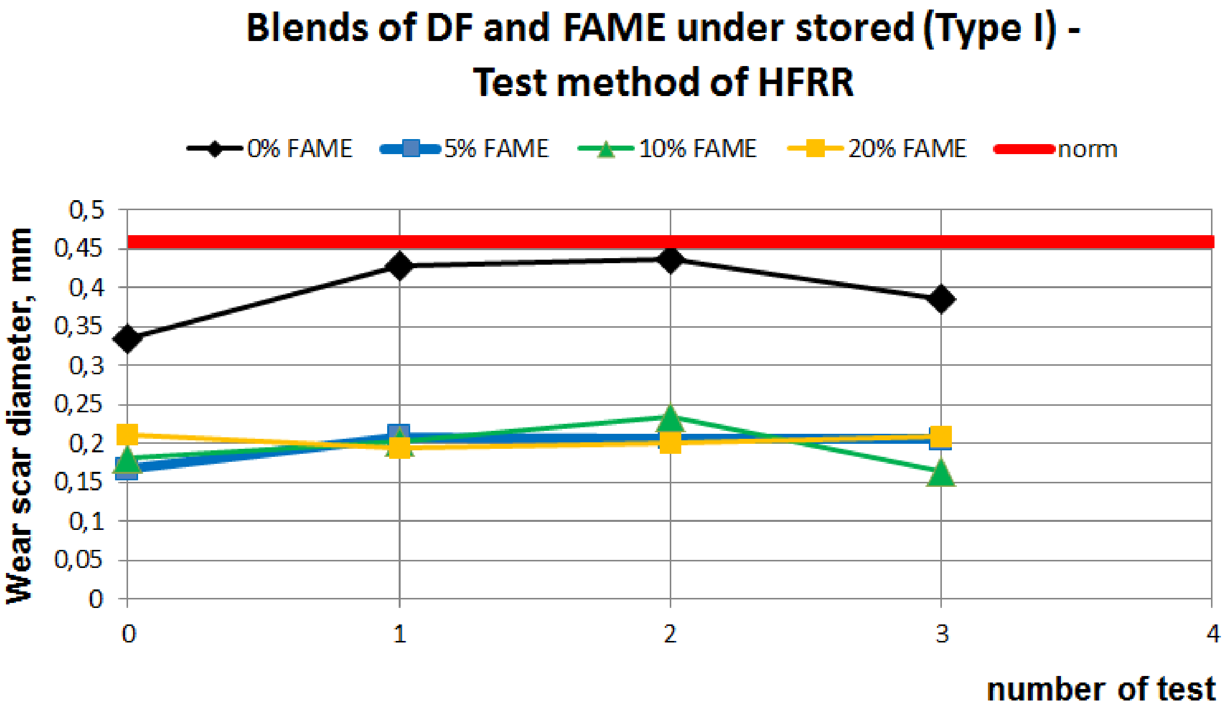


Fig.4. Lubricity of diesel fuel and FAME blends (Type I) during storage

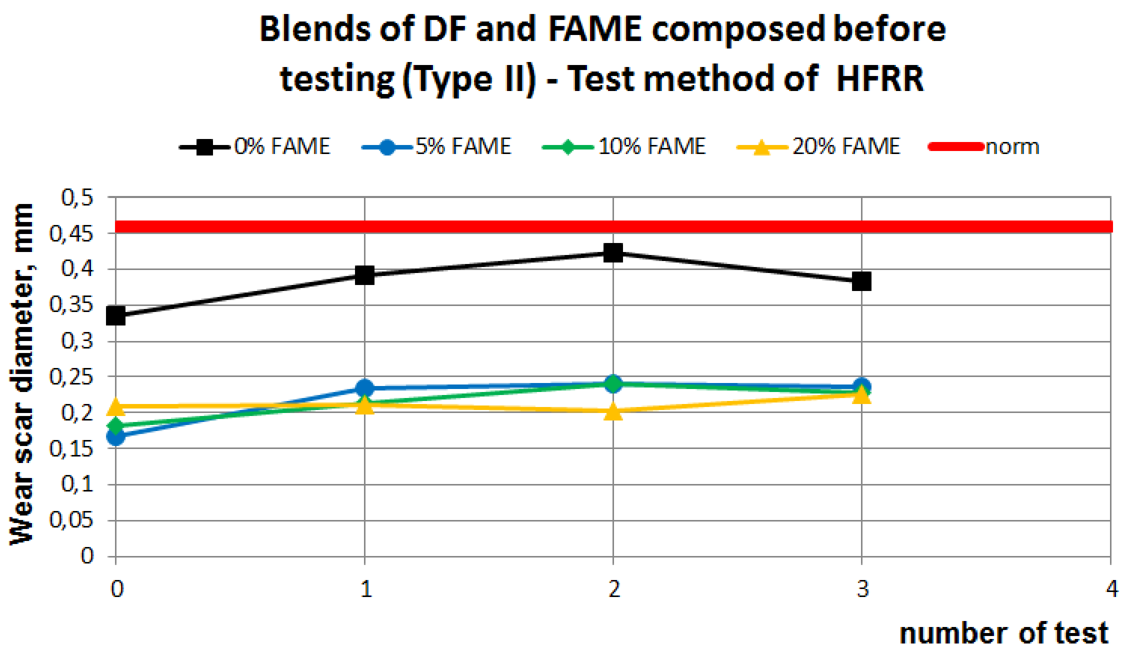


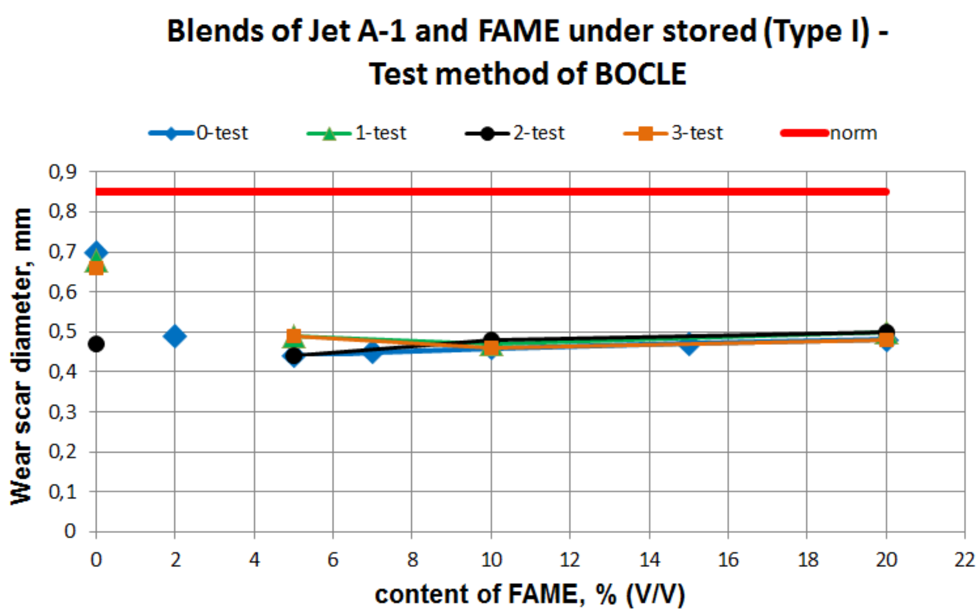
Fig. 5. Lubricity of diesel fuel and FAME blends (Type II) during storage

According to Fig. 2 to 5 we can assume that lubricity of blends of petroleum fuels (aviation Jet A-1 and diesel fuel) of different FAME content (5, 10 and 20 % vol.), estimated using standard test methods, generally doesn't change during analysed storage period. Time between test number „0" and „3" is 6 months. It's estimated that such storage period is too short to notice significant changes of lubricity.

Since the biggest fluctuations of wear scar diameter have been obtained for neat petroleum fuels (without FAME), we can confirm the expectation from chapter 3 that noticeable lubricity changes during storage relate to fuels of low FAME concentration. In case of diesel fuel, maximum test result was 436 µm (standard requirement 460 µm) so this is noticeable increase.

For all blends of Jet A-1 and diesel fuel with FAME, the lubricity at analysed storage period meet standard requirements in relation to neat petroleum fuels. According to relevant specifications, maximum wear scar diameter for Jet A-1 (BOCLE) is 0.85 mm, and for diesel fuel (HFRR) is 460 µm. The following figure shows selected test results at another data set.

a)



b)

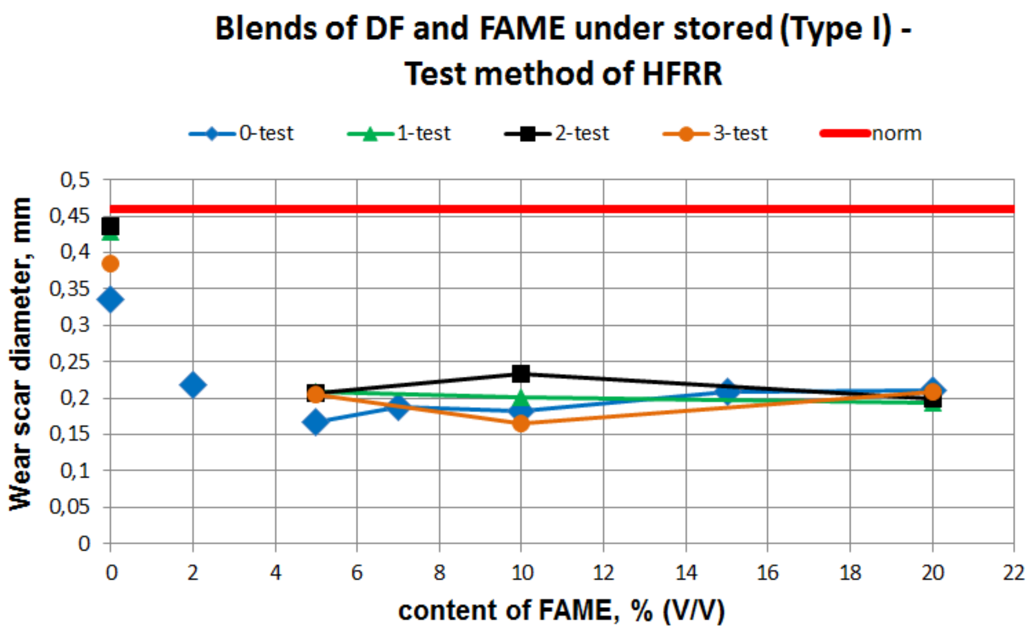


Fig. 6 Lubricity of mineral fuels and FAME blends (Type I) during storage a) aviation fuel and FAME, b) diesel fuel and FAME

Tests performed using standard devices BOCLE and HFRR show that FAME content (up to 20 %) effects on lubricity improvement of blends (smaller wear scar diameter) in relation to the same properties for neat petroleum fuel. In fig. 6 we can see that FAME content increase results in wear scar diameter decrease. Such tendency, however, is true up to appr. 5 % (vol.) FAME contribution in fuel. Then, despite FAME concentration increase, the wear scar diameter actually doesn't change.

The following figures show overall lubricity test results for model blend of mineral fuel with 5 % FAME concentration, covering two types of blends (Type I and II).

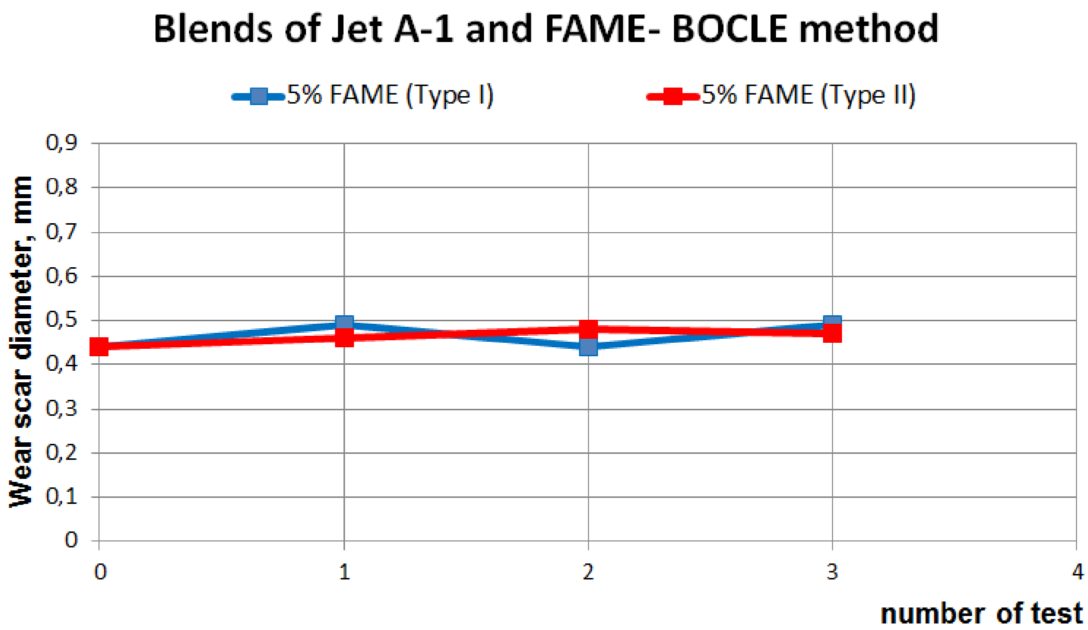


Fig. 7. Lubricity of selected blend of aviation fuel and FAME duringt storage depending on type of the blend

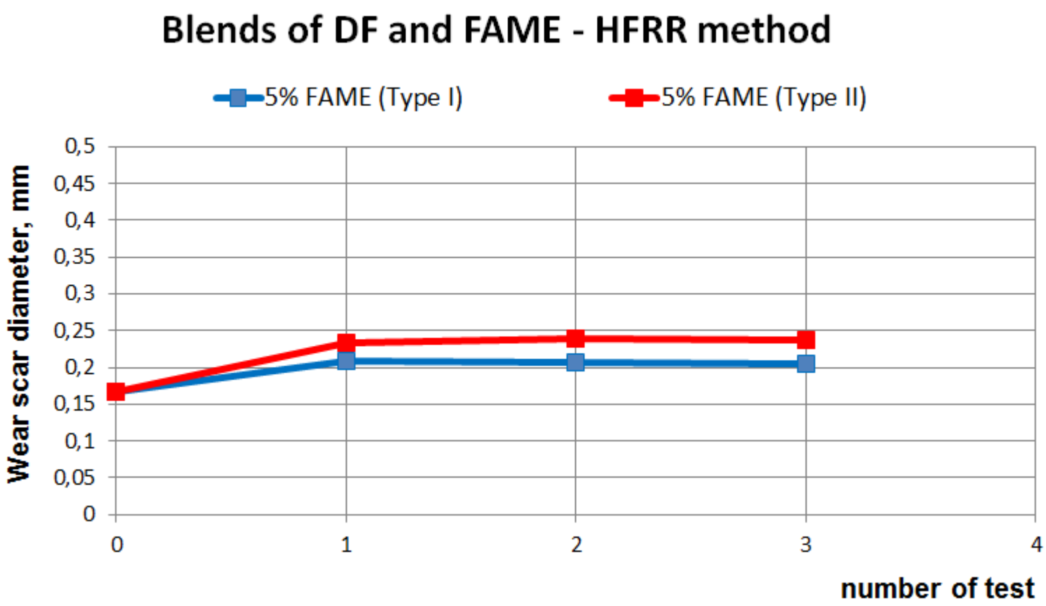


Fig. 8. Lubricity of selected blend of diesel fuel and FAME duringt storage depending on type of the blend

According to above Fig. 7 and 8 we can see that type of the blend of mineral fuel with 5 % FAME content has no significant effect on lubricity. It means that way of blending doesn't matter. It doesn't matter whether testing is performed using premixed base products (Type I) or using blends of separately stored base products, mixed together before testing (Type II). Such pattern is confirmed at whole considered storage period, also in relation to other FAME concentrations under testing.

5. Summary

Taking into consideration obtained test results we can formulate the following conclusions:

1. BOCLE and HFRR lubricity of mineral fuels containing 5, 10 and 20 % of FAME doesn't change noticeably during initial storage period (appr. 6 months). Wear scar diameter fluctuations are the most noticeable in case of neat mineral fuels, especially the diesel fuel.
2. The biggest differences of wear scar diameter in relation to neat mineral fuel (0 % FAME) were noticed for blends containing up to 5 % (vol.) of FAME. There were no significant difference above this level.
3. The way of blending mineral fuels and FAME doesn't influence the lubricity. Similar results were obtained both for mixed base components, and then stored as homogenous blend, and blends obtained from stored base components mixed just before laboratory testing.
4. In order to evaluate wear scar size during longer storage, the lubricity testing should be continued. It would allow to verify the laboratory test results in relation to real operation.

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