EXPERIMENTAL RESEARCH ON BIODIESEL COMPATIBILITY WITH FUEL SYSTEM ELASTOMERS

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Abstract. Biodiesel use in motor vehicles has become more popular during the last decade. In spite of that, different questions according to biodiesel compatibility with fuel system elastomers are not fully resolved and are still topical. Nowadays, different materials are used in production of gaskets, fuel hoses, o-rings, etc. and large part of them are fully compatible with fossil fuel, but not with biodiesel or its blends. Therefore, complicated research was performed in the Motor Vehicle Institute of the Latvia University of Agriculture the aim of which was to investigate the comparative degradation of physical properties of different elastomers (ethylene propylene diene monomer (EPDM), nitrile rubber (NBR), hydrogenated nitrile butadiene rubber (HNBR), fluorocarbon material (FKM), as also 2 polyamide materials (PA 10.10 and PA 12) in contact with fossil diesel, biodiesel and blend of those fuels (B30). The tests were carried out at room temperature (20 °C) for 1000 h. Different physical parameters like thickness, outside diameter and elongation were analyzed. The research results showed that O-rings produced from such material as FKM can be not influenced by biodiesel and its blend seriously. There were not observed any changes in the outside diameter and elongation. The most impacted material was EPDM, which showed increase in the thickness of O-rings by 30 %, outside diameter by 22 % and reduction of elongation using all types of fuels. The overall sequence of compatible elastomers in biodiesel produced from rapeseed is found to be: FKM > PA 10.10 > PA 12 > NBR > HNBR > EPDM.

Keywords: biodiesel, compatiblity, elastomers.

Introduction

During the last decade biodiesel is extensively studied as a substitute of a fossil diesel in compression ignition engines putting attention mainly on research of combustion parameters and environmental impact of the fuel use. Based on conclusions and beneficial features of the fuel, the introduction of it is realized in many countries produced from very different feedstocks and used in various proportions in mix with petroleum diesel. Currently, large part of biodiesel is used in Europe as mandatory admixture of biodiesel to petroleum diesel till 5 to 7 % in automobiles. Only some companies use also mixtures with the biodiesel content till 30 % or higher.

Previously performed researches confirm that biodiesel has a variety of different benefits, but it also has disadvantages, which make the use of it in automotive area more complicated compared to traditional petroleum diesel. For example, due to its unsatured molecules and compositional effects, it is more oxidative and causes enhanced corrosion and material degradation [1]. Therefore, the main part of diesel engine components, which comes in contact with biodiesel could be affected and there could be observed the degradation process of elastomers like seals, gaskets, hoses, and corrosion of metallic parts of filters, pumps, nozzles, etc. Fluids, like biodiesel, can cause mainly chemical degradation, cracking and swelling. Except the fluids, degradation of elastomers could be promoted also by many other factors: temperature, humidity, bio-organisms, mechanical stress and electrical stress [2].

In spite of very similar technical properties of petroleum diesel and biodiesel, the last one is very sensitive to many different factors, for example, storage time and conditions, production out-of-specification, types of used catalysts and feedstock, etc. Therefore the chemical nature of the fuel is impacted leaving consequences on the fuel compatibility with different materials.

There could be found researches investigating biodiesel impact on different materials, these researches are mainly concentrated on the corrosion effect of biodiesel [3] or elastomer researches are done using biodiesel produced from palm oil [1] or soybean oil [4], which differs in the physico-chemical characteristics from rapeseed based biodiesel produced and used in Latvia. It should be noted that elastomer compatibility may also depend on the feedstock and catalyst used for the production of biodiesel [5].

The main part of the tests for such researches were done using continuous immersion tests with the research in the structural changes of material taking into account that the absorption of the fuel and the extraction of soluble components such as plasticizers and additives are different for each type of elastomer [6]. Most researches confirm that, showing a little bit different results. For example, *Haseeb* [7] found that NBR after immersion in 100 % palm oil biodiesel loses 42.39 % tensile strength and 12.28 % hardness, but *Trakarnpruk* [6] found reduction in the tensile strength by 22 %, but increase in hardness by 5 % for the same material type. At the same time fluoro-viton did not show any significant structural change.

The aim of this research is to find out changes of the physical properties of the selected elastomers, (used in the fuel system of diesel vehicles) during the degradation process in contact with rapeseed oil biodiesel.

Materials and methods

The tests were performed in the fuel laboratory of the Motor Vehicle Institute of the Latvia University of Agriculture. The following fluids were included in the investigation: rapeseed derived biodiesel (coded as B100), commercial petroleum diesel (coded as B0) and biodiesel/petroleum diesel blend where 30 % were biodiesel and 70 % fossil diesel (coded as B30). Commercial diesel fuel used in the tests was purchased in the local fuel station and meets all the requirements for the standard LVS EN 590. Biodiesel used in this study was supplied by the Latvian company Bioventa (Latvia) and it meets all the requirements for the standard LVS EN 14214:2012. Fuel was tested in the Latvian Certification Centre and some characteristics of it can be found in Table 1.

There were used such materials for the tests: ethylene propylene diene monomer (EPDM), nitrile rubber (NBR), hydrogenated nitrile butadiene rubber (HNBR), fluorocarbon material (FKM), polyamide PA 10.10 and polyamide PA 12. The materials were received as parts provided for the use in the fuel system of diesel engines. The tests were done with both – O-rings and hoses. O-rings were used in such a condition as received, but hoses were cut to smaller pieces (about 50 mm), which allowed to prepare 4 samples of material per test.

The test was carried out with the samples placed in bottles containing 300 ml of fluid, under a constant temperature of 20 ºC. Examination of the materials was realized after 1000 hours. Baseline samples were also prepared and they were only exposed to ambient laboratory room temperature. After immersion, the following measurements were done: measurement of thickness and the outside diameter by stainless steel vernier caliper with 0,1 mm of accuracy, break load by machine *Zwick/Roell Z2.5*.

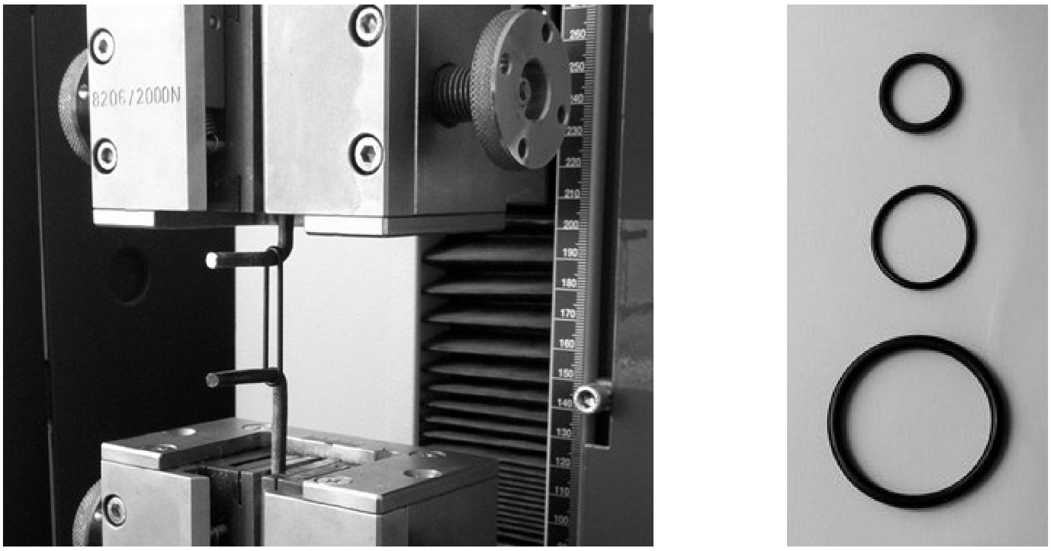

Fig. 1. **Break load testing machine *Zwick/Roell Z2.5* during the test of O-ring and some samples of O-rings used in the test**

During the tests the changes of extension per unit length or elongation ε (%) was calculated using the formula:

$$\varepsilon = \frac{\Delta L}{L_0} \cdot 100\,\% , \tag{1}$$

where ΔL – measured extension, mm;
L_0 – original length of the hose/O-ring, mm.

Table 1

Properties of biodiesel used in the tests

Property	Unit	Result	Method
Fame content	% (m·m^{-1})	99.1	LVS EN 14103:2011
Viscosity 40 ºC	mm^2·S^{-1}	4.494	LVS EN ISO 3104:2003 – AC
Water content	mg·kg^{-1}	4.4	LVS EN ISO 12937:2002
Acid value	mg KOH·g^{-1}	0.31	LVS EN 14104:2003
Iodine value	g J$_2$·(100g)$^{-1}$	108	LVS EN 14111:2003
Methanol content	% (m·m^{-1})	0.04	LVS EN 14110:2003
Monoglyceride content	% (m·m^{-1})	0.48	LVS EN 14105:2011
Oxidation stability	h	13.2	LVS EN 14112:2003

Results and discussion

Table 2 shows the summary of thickness of O-rings and outside diameter of hoses after of 1000 h of immersion of materials in rapeseed biodiesel (B100), 30 % biodiesel blend with petroleum diesel (B30) and petroleum diesel (B0). It can be observed that O-rings produced from FKM and HNBR practically are not influenced by any of the mentioned fluids. The largest changes were observed in the case of O-rings produced from EPDM, the thickness of which increased not only in biodiesel contained fluids, but also in petroleum diesel. Therefore, it could be affirmed that FKM and HNBR produced O-rings are more compatible with biodiesel and its blends than EPDM.

Table 2

Changes of thickness of O-rings and outside diameter of hoses

Material type	Base	B0	B30	B100
O-rings				
EPDM	3 mm	+13 %	+33 %	+33 %
FKM	2.1 mm	0	0	0
HNBR	1.6 mm	0	0	0
Hoses				
EPDM	19.5 mm	+21 %	+21 %	+22 %
NBR	12 mm	+4 %	+4 %	+7 %
PA10.10	8 mm	0	0	0
PA12	8 mm	0	0	0

The immersion tests carried out with hoses followed a similar protocol as that of O-rings. The hoses produced from EPDM experienced largest increase of the outside diameter not only with biodiesel, but also in petroleum diesel. A similar tendency, but with smaller increase in values was observed also with NBR.

The results of elongation for O-rings are presented in Fig. 2. The research showed that EPDM was affected more by petroleum diesel than biodiesel, while HNBR was affected more by biodiesel. FKM was the only material which showed the best compatibility with all fuels and was not practically affected in case of elongation. Therefore, the usage of this material for production of O-rings is recommended.

A similar situation was observed also in the case of hoses (Fig. 3). The use of petroleum diesel reduced elongation of EPDM compared to the base example more than 3 times, while the use of biodiesel reduced elongation only 1.36 times. In total it should be noted that this type of material showed the worst results and therefore it cannot be used in contact with any type of hydrocarbons, oils and esters.

NBR showed the most promising results in the elongation test as it did not increased more than 1 % to 6 % based on the fuel type compared to the base example. Therefore, it should be recommended in use with petroleum diesel, biodiesel and its blends, but there is a necessity to check regularly the outside diameter of hoses as it has tendency to increase and could impact the work of the fuel system.

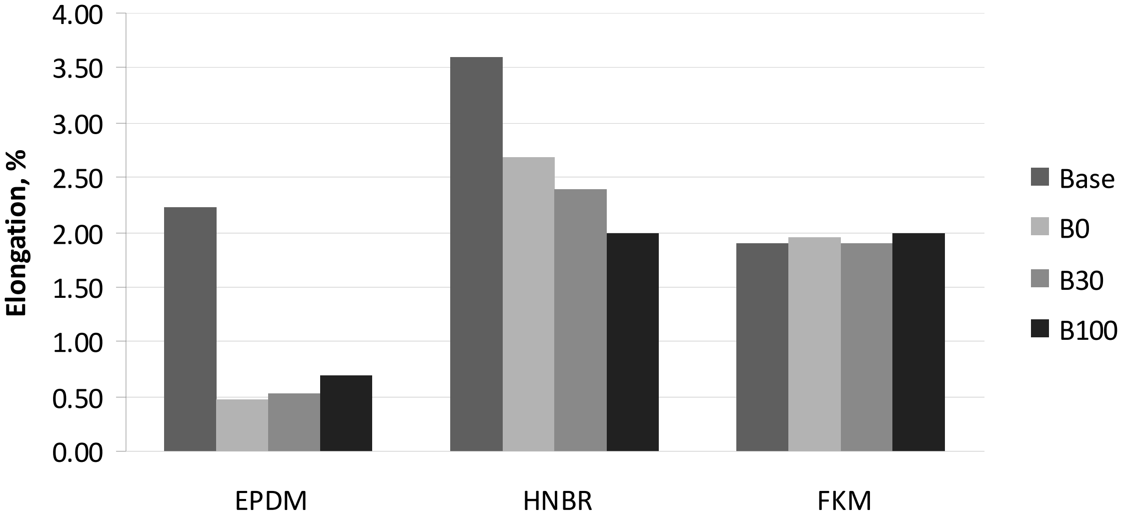

Fig. 2. **Changes of elongation of O-rings produced from different materials**

Positive results were observed also in case of polyamide materials PA 10.10 and PA 12.12. If PA 10.10 did not show any changes in the elongation test in contact with B100 compared to the base sample, then PA 12.12 did not show any changes in the elongation test in contact with petroleum diesel compared to the base sample. Therefore, it could be concluded that each of the materials is more suitable for specific liquid or fuel use.

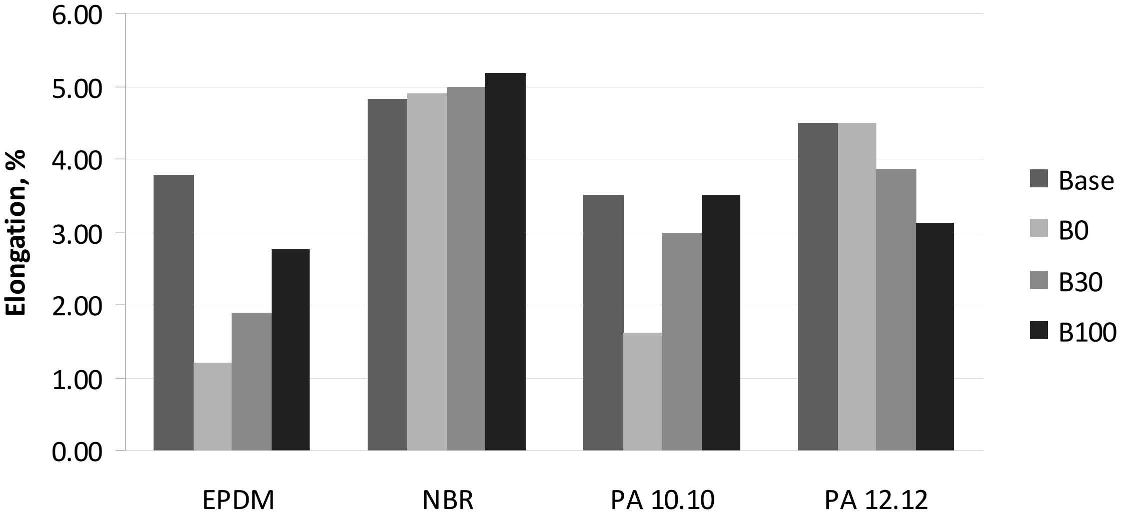

Fig. 3. **Changes of elongation of hoses produced from different materials**

Conclusions

1. Rapeseed oil biodiesel has shown greater impact on thickness and the outside diameter of elastomers like EPDM and NBR. On the other hand, petroleum diesel also had shown an impact on these elastomers, but in smaller scale than B100. The changes of the physical properties of other tested materials were not significant.
2. Only few materials, like FKM and NBR, preserved the same properties in the elongation test as the baseline samples. The main part of all other materials has shown reduction in elongation even after immersion in petroleum diesel.

3. The overall sequence of compatible elastomers in rapeseed oil biodiesel is found to be: FKM > PA 10.10 > PA 12 > NBR > HNBR > EPDM.
4. Systematic investigations of elastomers in contact with biodiesel would be required to explain the exact mechanisms of degradation and the potential influence of different factors.

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