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THE INFLUENCE OF FATTY ACID METHYL ESTERS ON SEALING ELEMENTS OF FUEL FILTERS

One of the main difficulties associated with the use of FAME biofuel (fatty acid methyl esters) in its pure form as an engine fuel is its destructive effect on fuel system components made with traditional materials. This applies to both elements made out of metal (corrosive effect), as well as synthetic materials. This study attempts to assess the impact of FAME biofuel on sealing elements of fuel filters, which are made of fluorine rubber and nitrile butadiene rubber. The results showed that the mechanical properties of fluorine rubber do not change in the conditions of prolonged contact with FAME. Thus, it can be safely used in fuel systems for engines fuelled with FAME as a neat fuel.

Key words: FAME, fuel filter, seals, elastomers

1. INTRODUCTION

Transport is a major consumer of fuels produced from petroleum. Information warning about the end of petroleum resources has been around for decades, and despite the growing scale of oil consumption the warnings still fail to be reflected in oil production. In 2014 average Brent crude oil price was 98,93 USD per barrel and fell to 52,47 USD after a year. Such a significant drop in oil prices clearly shows that the price of oil is more determined by political factors than diminishing resources. Although depletion of raw materials for the production of petroleum-based fuels is not a threat for the near future, it is worth to take action to increase the production of biofuels. This will allow to reduce dependence on imported oil, or activate agricultural production.

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The most used motor fuel in the European Union is the diesel fuel [Benazzi 2011]. It is expected that the disparities in the use of petrol and diesel fuel in the European Union will continue to increase. A similar situation exists in Poland, where the consumption of diesel is three times more than that of gasoline (Fig. 1). Taking further into account that in the processing of crude oil more gasoline is usually obtained than diesel fuel, no further reasons for the search for alternatives to the latter should be needed.

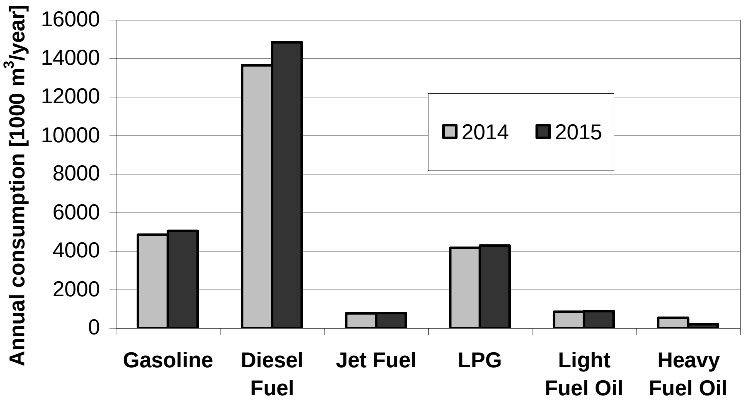

Fig. 1. Annual consumption of petroleum fuels in Poland [Główny Urząd Statystyczny 2015, Polska Organizacja Przemysłu... 2015]

Biofuels can be distinguished into four generations of fuels, but the only ones to still have a market significance are the first-generation biofuels: ethanol – for spark ignition engines and fatty acid methyl esters (FAME) – for diesel engines. Despite the conducted research and development at the moment there are no indications that higher generations of biofuels could gain a significant share in the fuel market in the near future. So FAME still remains the primary replacement for diesel fuel.

FAME fuel is characterized by physicochemical properties slightly different than diesel fuel. Overview of the technical and operational benefits and risks associated with the use of this fuel in internal combustion engines Merkisz presented together with collaborators in [Merkisz and Kozak 2003, Merkisz, Kozak and Teodorczyk 2003]. Among the advantages of FAME listed there were: a high cetane number, good lubricating properties, good biodegradability and favourable changes in exhaust emissions. The disadvantages of FAME are among other things: a lower calorific value, poorer low temperature properties, hygroscopicity and susceptibility to microbial contamination, corrosive effect to some metals and reduction of the durability of fuel system components made of conventional elastomers. The importance of the latter problem is the fact that the adaptation of an engine to use FAME mainly relies on the use of FAME-resistant elements for the supply system. When using FAME, the element that is continuously in contact with the fuel is also the fuel filter. This paper presents the results of studies on the impact of FAME on sealing elements for fuel filters made of different elastomer materials.

2. MATERIALS USED FOR SEALING OF THE FUEL FILTERS

2.1. Nitrile butadiene rubber (NBR)

In the trade nitrile butadiene rubber, also known as NBR, is often seen under many other trademark names, such as: Butacril, Elaprim, Europrene, Hycar, Krynac and Nitriflex. NBR is a copolymer of acrylonitrile and butadiene. The content of the former may reach 18÷50%. The higher the content, the higher the resistance to high temperatures.

NBR with 18% content of acrylonitrile is characterized by [Passerotti 2016]:

– average resistance to oils and fuels,
– good resistance to low temperatures (up to about –38 °C).

NBR with 50% content of acrylonitrile is characterized by [Passerotti 2016]:

– very good resistance to oils and fuels,
– poorer resistance to low temperatures (up to about –3 °C).

The temperature range of application of NBR is: –30°C to +100 °C (briefly +150 °C). Nitrile butadiene rubber vulcanizates are characterized by high flexibility, oil resistance, tear strength, and low permanent deformation at compression.

Acrylonitrile vulcanizates are resistant to [Passerotti 2016]:

– water up to 60 °C (specific types up to +100 °C),
– aliphatic hydrocarbons such as propane, or pure gasoline,
– oils of vegetable or animal origin,
– light heating oils and fuels for diesel engines,
– non-flammable hydraulic fluids such as: HSA, HSB (oil-in-water emulsions) and HSC polyglycols mixture with water,
– lubricants and mineral oils,
– diluted acids and alkalis at low temperatures.

Acrylonitrile vulcanizates are not resistant to [Passerotti 2016]:

– motor oils and greases,
– aromatic and chlorinated hydrocarbons, for example: benzene,
– brake fluids based on glycols,
– esters and polar solvents,
– HSD type of hydraulic fluids.

2.2. Fluorocarbon rubber (FKM)

Fluorocarbon rubber (FKM) is a copolymer of fluorine-containing monomers. Trade names of this type of elastomer include: Dai El, Fluorel, Noxitite, Tencoflon and Viton. Its temperature range of application is: –25 to +200 °C (briefly +230 °C). FKM materials are non-flammable and exhibit an exceptional thermal and chemical resistance. They have a low permeability to gases and minimal weight loss under vacuum conditions.

Fluorinated vulcanizates are resistant to [Passerotti 2016]:
- oils and mineral greases also with additives,
- synthetic oils for aircraft engines,
- flame-resistant hydraulic fluids based on phosphate esters and chlorinated hydrocarbons (HSC),
- aliphatic and aromatic hydrocarbons,
- UV radiation,
- ozone and aggressive chemical compounds.

Fluorinated vulcanizates are not resistant to [Passerotti 2016]:
- hot water and steam,
- ketones, esters and low molecular weight ethers, such as ethyl acetate,
- organic acids, e.g.: acetic, formic,
- concentrated solutions of sodium hydroxide and acids.

3. RESEARCH METHODOLOGY

The study involved the previously mentioned two types of elastomeric sealing elements used in fuel filters for diesel engines, namely: fluorocarbon rubber and nitrile butadiene rubber. For the study of material strength and resistance, dumbbell samples were prepared (Fig. 2 and 3) according to PN-ISO 37:2007.

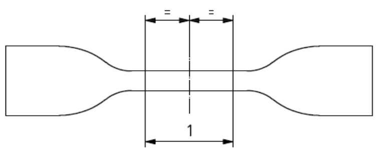

Fig. 2. The shape of the test samples

Fig. 3. The extruded material produced with a die (dumbbell specimen)

The samples were exposed to FAME (completely immersed in biofuel) for a period of five months. Every 20 days a measurement of parameters such as tensile strength, elongation at break, hardness and density was conducted. Tensile strength and elongation at break were measured using a Zwick testing machine BZ2.5/TN1S, hardness was measured using a Shore (in scale A) durometer, and the density using a METTLER AE260 DeltaRange scale.

The study used the commercially available (from a network of petrol stations BLISKA) FAME fuel (B100) consisting of 100% fatty acid methyl esters from vegetable oils. The quality of this fuel was in accordance with the Regulation of the Minister of Economy on quality requirements for liquid fuels [Rozporządzenie..., 22.01.2009].

4. TEST RESULTS AND DISCUSSION

The research results presented are the average values of the three measurements of tensile strength and elongation at break and five measurements of the hardness and density.

As is apparent from the data presented in Figure 4 the tensile strength of nitrile butadiene rubber (NBR) is about 50% higher than for the fluorine rubber (FKM). After prolonged exposure to FAME FKM material strength is not affected. The strength of the NBR in contact with FAME quickly drops to a level similar to the FKM, i.e. about 8 N/mm^2. What is characteristic despite further exposure to the effects of FAME the tensile strength of NBR is no longer changed after the initial drop.

The same applies for both plastics changes in elongation at break (Fig. 5). This parameter for new materials is twice that of the FKM. Under the influence of FAME it quickly drops to a level of 250–270%, and it remains in that range for the next few months while in contact with the biofuel. In turn, FKM elongation at break remains at a constant value (about 200%) throughout the study period of exposure to FAME.

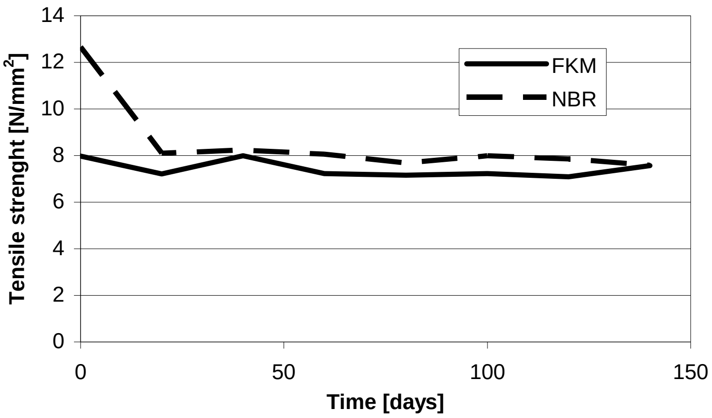

Fig. 4. Changes in the tensile strength of fluorine rubber (FKM) and nitrile butadiene rubber (NBR) in contact with FAME

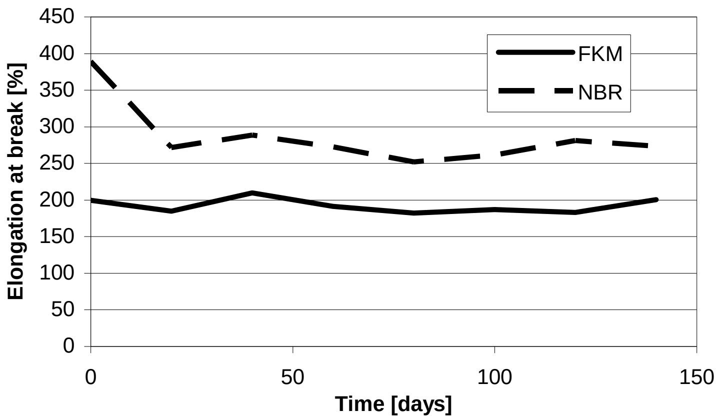

Fig. 5. Changes in the elongation at break of fluorine rubber (FKM) and nitrile butadiene rubber (NBR) in contact with FAME

Hardness of FKM is another parameter that does not change for the material after exposure to FAME (Fig. 6). For both new materials FKM and NBR hardness values are similar, 60–70 HS (in scale A of the durometer Shore method). When in contact with FAME the hardness of NBR gradually decreases to stabilize at around 40 HS after approximately 80 days.

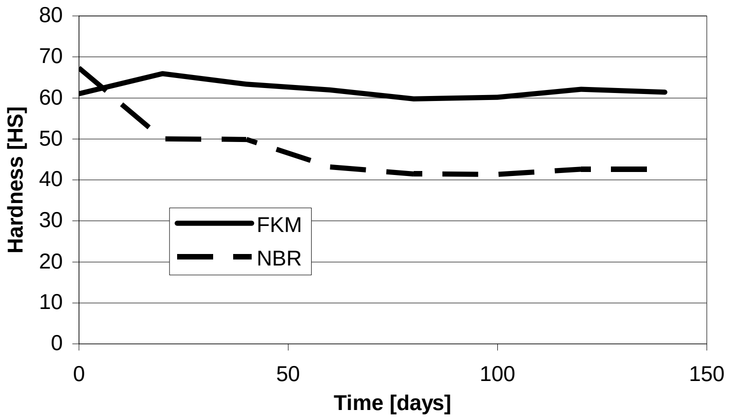

Fig. 6. The hardness of fluorine rubber (FKM)
and nitrile butadiene rubber (NBR) in contact with FAME

The density is only one of the parameters studied, which for both materials is not altered by prolonged contact with FAME (Fig. 7). For the FKM it is about 1.8 g/cm^3, and for the NBR it levels at approximately 1.2 g/cm^3.

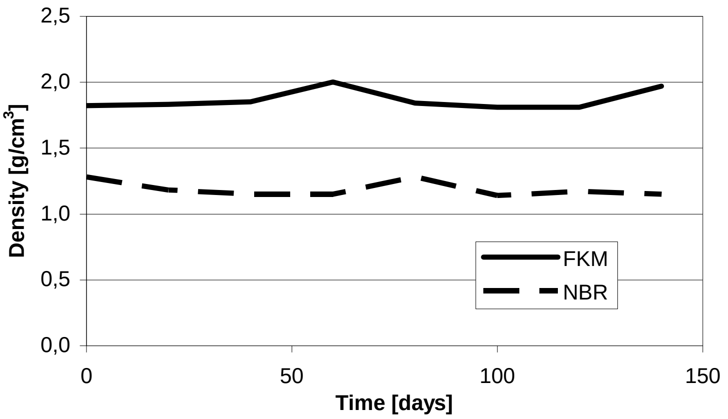

Fig. 7. Changes in the density of fluorine rubber (FKM) and nitrile butadiene rubber (NBR) in contact with FAME

5. CONCLUSIONS

Performed tests have shown that the materials used for the production of sealing elements in fuel filters have different resistance to the effects of FAME. Fluorocarbon rubber (FKM) exhibits excellent resistance during long-term (5 months) exposure to FAME – parameters such as tensile strength, elongation at break, hardness and density are not changed. Nitrile butadiene rubber (NBR) is less resistant. Its mechanical properties and hardness are substantially reduced in the initial period of exposure to FAME, but after a further period already remaining at constant value. FKM-type material can therefore be successfully used in applications requiring long-term resistance to the effects of FAME biofuels such as the sealing for the fuel filters. It is worth noting that the market offers a family of FKM materials with increased resistance to oxygenated fuels. It is, for example, Viton F which is characterized by a high fluorine content (about 70%).

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WPŁYW ESTRÓW METYLOWYCH KWASÓW TŁUSZCZOWYCH NA ELEMENTY USZCZELNIAJĄCE FILTRÓW PALIWA

Streszczenie

Jednym z głównych problemów związanych z zastosowaniem biopaliwa FAME (estry metylowe kwasów tłuszczowych) w czystej postaci jako paliwa silnikowego jest jego destrukcyjne oddziaływanie na elementy układu paliwowego wykonane z tradycyjnych materiałów konstrukcyjnych. Dotyczy to zarówno elementów wykonanych z metali (oddziaływanie korozyjne), jak i z tworzyw sztucznych. W niniejszej pracy podjęto się oceny wpływu FAME na elementy uszczelniające filtrów paliwa, które wykonywane są z kauczuku fluorowego i kauczuku akrylonitrylowego. W wyniku badań stwierdzono, że właściwości mechaniczne kauczuku fluorowego nie zmieniają się w warunkach długotrwałego kontaktu z FAME. A zatem może być on bezpiecznie stosowany w układach paliwowych silników zasilanych FAME jako samoistne paliwo.

Słowa kluczowe: FAME, filtr paliwa, uszczelnienia, elastomery