INFLUENCE OF BIOBUTANOL ON WEAR OF FUEL INJECTION SYSTEM

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Abstract
Effort to reduce the consumption of fossil energy sources leads to their replacement by renewable sources. In the automotive industry it is substitution of diesel and petrol with biofuels based on bio-oils and bioethanol, mainly from crop production. Fuel injection systems of modern combustion engines work with high operational pressures. This is possible because of precise manufacture of individual parts of fuel injection system. Fuel quality has a vital impact on the wear of these important components. The aim of this paper is to compare the impact of biofuels on the wear of the fuel injection system. During the experiment were examined mixtures of diesel oil and biobutanol. For analysis was used tribometer Reichert tester M2. Part of real fuel injector was used as a test roller. Paper proved the hypothesis that greater share of biofuels in conventional fuels increases wear of parts of fuel injection system.

Key words: reichert tester, wear, bioethanol, fuel injection system.

INTRODUCTION

Surface preparation is an important factor for the practical application of machine components, particularly in situations such as the precise alignment and high strength applications. It is necessary to pay attention to optimization of machining process. Influence of machining is a significant factor affecting the life of machine components within various applications (MÜLLER ET AL., 2013).

Parts of fuel injection system are very difficult in terms of surface preparation and choice of proper materials. Fuel injection systems of modern combustion engines also work with high operational pressures. Fuel quality has a vital impact on the wear of these important components. Effort to reduce the consumption of fossil energy sources leads to their replacement by renewable sources (MAŘÍK ET AL., 2014). In the automotive industry it is the substitution of diesel and petrol with biofuels based on bio-oils and bioethanol, mainly from crop production (HÖNIG ET AL., 2015).

Newly produced biofuels can lead to increased wear of the fuel injection system due to reduced lubrication capability compared to conventional fuel. Increased wear of the fuel injection system leads to failures and reduces durability of the entire fuel injection system. Increased wear of the fuel system is associated with the formation of the wear particles, which consequently accelerate the process and the intensity of wear (HÖNIG ET AL., 2014).

Wear is a permanent adverse change on the surface or dimensions of rigid bodies, caused by the interaction of functional surfaces, or functional surface and medium which causes wear. Wear occurs as a removal or relocation of particular matter from the surface by mechanical effects, sometimes accompanied by other factors, such as chemical or electrochemical. Generally, there can be classified six basic types of wear: adhesive, abrasive, erosive, cavitation, vibration and fatigue (VALÁŠEK, MÜLLER, 2015).

Adhesive wear is typical for cases where there is a slip of two rigid bodies, together forced down with normal force. As a result of contact between them there occurs the rupture of adsorption layers and surface oxide layers and creation of the interfacial micro-junctions, which are subsequently disarranged. Such a process generates particles having the shape of flakes with a diameter of 5 to 10 μm and a thickness of 0.25 – 0.75 μm, the size should not exceed 15 μm. The shape of adhesive particle is shown in Fig. 1. Adhesively worn surface is smooth, polished (PEXA ET AL., 2015).

Abrasive wear is typical for cases when two surfaces are in contact and that one or both are rough and hard, or in case when there are presented free particles between two hard surfaces. The abrasive particles have shape of wires, spirals, chips with a length of tens to hundreds of micron and tenth micron of thickness. Abrasively worn surface is rough, scratched (MÜLLER ET AL., 2015).

Fatigue wear is characterized by progressive accumulation of defects in the functional surface layer during repeated contact stress (roller bearings, gear wheels, etc.). Fatigue wear particles may have a spherical (round) shape with a diameter of 2 – 5 µm, laminar as a result of pressing laminar spherical particles in the path of the bearing roller and may have the shape of triangles of size up to tens of µm (MÜLLER ET AL., 2010).

The aim of this paper is to prove or disprove the hypothesis that biofuels increase wear of parts of fuel injection system.

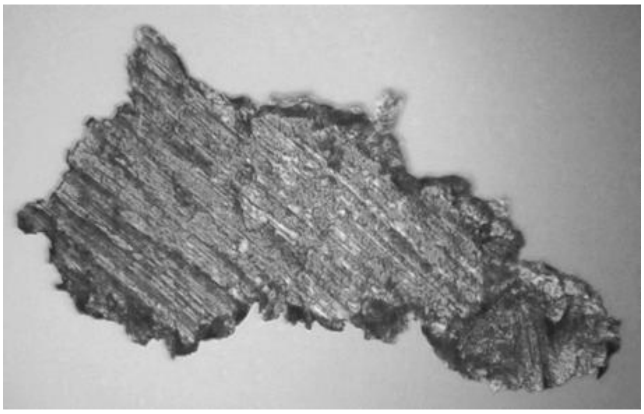

Fig. 1. – Example of shape of adhesive particle (ALEŠ ET AL., 2016)

MATERIALS AND METHODS

The aim of the measurements was to assess the impact of biobutanol (according to different share of biobutanol in diesel fuel) on wear of fuel injection system. Standard ISO 12156-1:2006 is used as a test method using the high-frequency reciprocating rig (HFRR), for assessing the lubricating property of diesel fuels. Test method according to EN ISO 12156-1 is not available at workplace of authors and therefore test device Reichert tester M2 was used. Reichert tester (Fig. 2) belongs to a group of devices which simulates real frictional contact. Frictional contact is evaluated by load carrying capacity of lubricating film. Test roller is firmly clamped and pushed by a weight on the rotating slip ring (made of specially alloyed steel) through a lever mechanism during a defined distance. The lower third of the slip ring is immersed in the oil bath. Sufficient quantity of oil is fed into contact with the test roller during rotation of slip ring. The better lubricity of the fuel is, the smaller elliptical area on the test roller is formed. The size of elliptical area A is calculated according to Equation 1.

$$A = \pi \cdot \frac{l}{2} \cdot \frac{d}{2} = 0.785 \cdot l \cdot d \qquad (1)$$

Where: A - elliptical wear area (mm^2); l - length of elliptical wear area (mm); d - width of elliptical wear area (mm)

For the purpose of the experiment there were prepared 10 test rollers (plungers of line high-pressure pump) of material used to produce components of fuel injection systems (element EA8Pg-35). Test rollers were cut using a cutter metallurgical Struers Discotom using a liquid coolant. Test rollers were shortened to the desired length, diameter was not machined. Hardness HV1 and HRC was measured at 30 points equally spaced on the surface of test roller. Vickers hardness at a low load i.e. HV1 (9.807 N) was measured on the surface of test roller. Hardness value HV1 was 839.4 ± 9.4, i.e. variation coefficient was 1.12%. Additionally, Rockwell hardness measurements using a scale HRC was done. The result of HRC value was 65.24 ± 0.31, i.e. variation coefficient was 0.47%. From the measurement results it is obvious an even hardness on the surface of the test samples.

Each test roller was used three times to test lubricating properties of the fuels at laboratory device Reichert tester. Tested fuels were as follows: pure diesel, diesel with a share of 25%, 50%, 75% of biobutanol and 100% biobutanol. Each fuel was subjected to tests of lubricating properties 6 times. Reichert tester was set to the following parameters: 50 m trajectory, 500 rpm and 1.5 kg weight load. Set parameters were lowered compare to standard parameters (100 m trajectory, 980 rpm and 1.5 kg weight load) due to safety reasons.

Elliptical wear area can be evaluated by use of the scanning electron microscopy (SEM) (HEINRICHS ET AL., 2014). There is a clearly recognizable difference between the machined surface and elliptical wear area (Fig. 3).

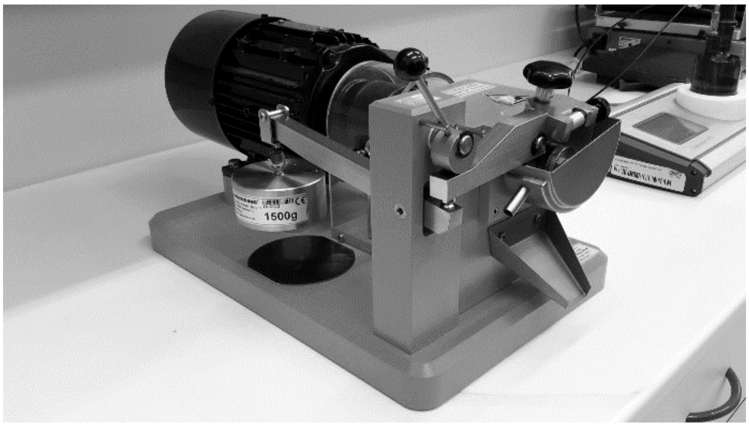

Fig. 2. – Reichert Tester M2

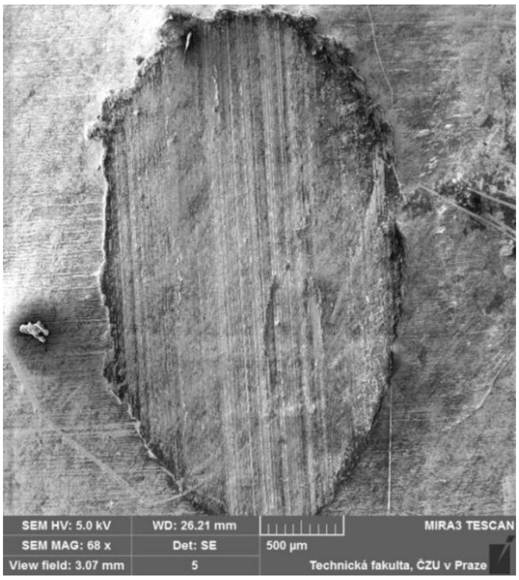

Fig. 3. – SEM image – Elliptical wear area after Reichert test (ALEŠ ET AL., 2016)

RESULTS AND DISCUSSION

Altogether of 30 measurements were performed on the device Reichert tester M2. Results of sizes of elliptical wear area are shown in Tab. 1.

Tab. 1. – Size of elliptical wear area after Reichert test according to different fuels

Number of Elliptical wear area	Size of elliptical wear area (mm^2)				
	Diesel	Share of biobutanol in diesel			Biobutanol
	100 %	25 %	50 %	75 %	100 %
1	22.9975	26.6084	25.0723	27.8678	26.2954
2	24.1769	26.2990	26.9214	25.3781	27.2345
3	25.0723	25.9896	27.8678	27.2345	28.1736
4	23.3557	26.2961	25.8518	26.7255	27.2586
5	23.6095	26.4011	27.7834	26.9239	27.2446
6	24.5855	26.4290	25.9985	26.1202	27.8052

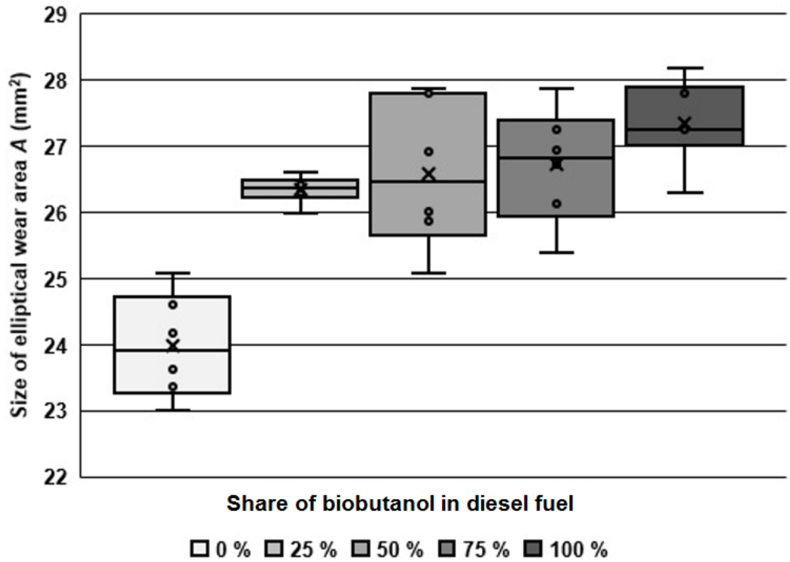

Fig. 4. – Size of elliptical wear area dependent on share of biobutanol in diesel fuel

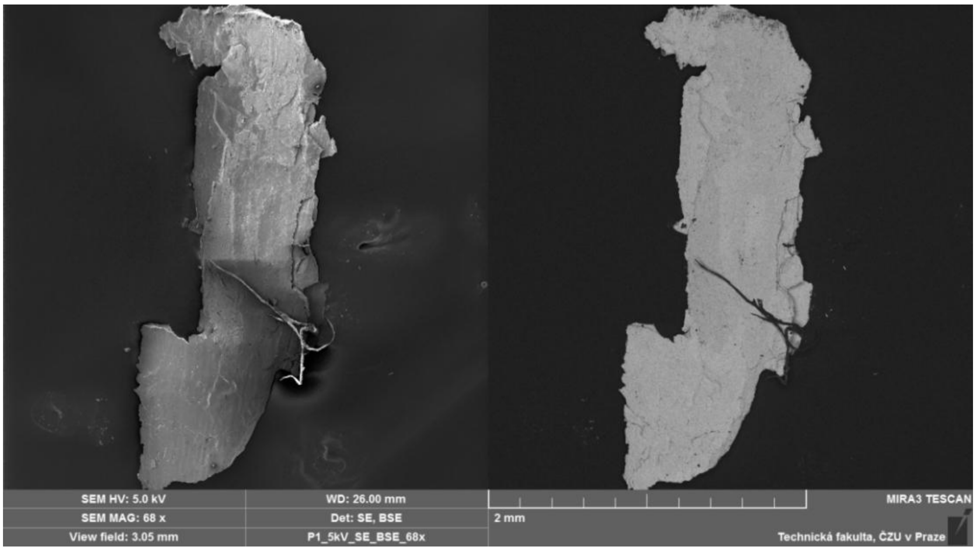

Fig. 5. – Abrasive wear particle generated during Reichert test with 100 % biobutanol

Box plot (Fig. 4) was created from the data in Tab. 1. From displayed data is obvious that a relatively small proportion of biobutanol in diesel causes a decline of lubricity, which affects the size of elliptical wear area. On average biobutanol has 12% larger elliptical wear area than pure diesel. Lower lubricity relate to the generation of wear particles. Loose wear particles can cause intense abrasive wear in the fuel systems particularly in the injector. These generated wear particles (Fig. 5) significantly reduces durability of the entire fuel system. Besides that, when the biobutanol dilute lubricating engine oil it often leads to a shortening of the recommended oil drains (between 30% and 60%) and an increase in wear (GILI ET AL., 2014).

CONCLUSIONS

Designed of used materials, surface finishing and precision of manufacturing are essential for a properly functioning system fuel system. Development of biofuels often raises the question of their ability to ensure proper lubrication capabilities in fuel systems. Described experiment was focused on measuring of lubricating properties of biobutanol as an alternative to diesel fuel. Reichert Tester M2 was used to verify this assumption. Results show that even a relatively low share of bioethanol in diesel has a significant influence on the size of elliptical wear area. Presence of biobutanol in diesel increases the size elliptical wear area on average by 12 %. Increase of the size of elliptical wear area comparing pure Diesel and pure biobutanol was even 14 %. The results show that biobutanol has a lower lubricating ability and it would be appropriate to verify this assumption in real operation. Other solution might be to consider possibility to suggest a suitable type of additive to enhance lubricating abilities of biobutanol.

ACKNOWLEDGEMENTS

Paper was created with the grant support – IGA CULS Prague 2016: 31190/1312/3117 Effect of mixtures of biofuels on production of nitrogen oxide and smoke of combustion engine during NRSC.

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