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Evaluation of vegetable and petroleum based diesel fuels in the aspect of lubricity in steel–aluminium association

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A b s t r a c t. The paper presents the results of a study on wear resistance of elements of injection system operating in steel-aluminium friction system with relation to the kind of fuel used. The fuels used in the study included regular petroleum-based diesel fuel, esters of colza oil, and their mixtures. The study, of a laboratory character, was done using a friction machine with a roller-ring friction couple. Such a combination allows to obtain the border friction which is based on the rule of transition from friction on the material surface to friction on the surface of adsorbed polar compounds. The persistence of lubricating film was evaluated as ability to counteract the wear of a sample made of aluminium.

On the basis of the research it was found that a small supplement of RME to diesel fuel causes a sudden increase of sample wear. The highest wear value was obtained with a 20% supplement of RME. The smallest value of wear of aluminium sample was obtained with the use of pure diesel fuel.

K e y w o r d s: RME fuel, diesel fuel, lubricity, steel, aluminium

INTRODUCTION

Agricultural machines and tractors are most frequently powered with Diesel engines. This is due to the fact that most agricultural machines require high torque at relatively low rotational speeds, and high traction power at slow motion speeds of agricultural tractors. An additional advantage of Diesel engines, in comparison to petrol engines, is their high durability, compact construction and resistance to unfavourable conditions during field work. Diesel engines are powered with diesel fuel which is a mixture of hydrocarbons of petroleum derivation. Diesel fuel is produced as a result of crude petroleum treatment in a process of refinement and a number of other processes aimed at improvement of its final parameters. The fuel system of Diesel engines is responsible for the preparation of air-fuel mixture. The primary function for that system is to inject fuel into the cylinders in appropriate amounts and at appropriate time of engine operation cycle. The appropriate spraying of fuel and its mixing with compressed air is of fundamental importance. The achievement of the optimum combustion conditions requires a reliable and precise fuel injection system.

Recently, a fundamental role in the operation of combustion engines is played by ecological aspects related with the emission of harmful compounds included in exhaust fumes. Among the most important of such compounds are: sulphur oxides (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), solid particles, and greenhouse gases – mainly carbon dioxide (CO_2). Also significant is the awareness of gradual depletion of oil resources, escalation of oil prices, and national security with respect to energy supplies. In view of the above, there is continuing research on the introduction of an alternative fuel that would be free of all of the unfavourable effects characteristic of the combustion of diesel fuel. Currently, the most suitable alternative fuel is methyl esters of colza oil (RME). This fuel is characterized by properties similar to those of diesel fuel, and its use in the form of mixtures with diesel fuel as well as in pure form does not require any changes in engine design (Baczewski and Kałdoński, 2004; Bocheński, 2003; Knothe and Steidley, 2005; Wei and Spikes, 1986). Numerous studies confirm that esters of colza oil have very good lubricity and they counteract wear considerably better than diesel fuel does. However, this is only true of the steel-steel friction couple (Majzner *et al*., 1998). There is a lack of information about the influence of esters on wear in the case of the steel-aluminium friction couple. Aluminium alloys are widely

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used in motor vehicle technology due to such properties as low specific gravity, relatively good mechanical strength, high resistance to corrosion, and good casting properties. The steel-aluminium friction couple association occurs very often in the fuel systems of compression-ignition engines, as well as in other devices used in the manufacturing, transportation and distribution of RME fuel, which fully justifies the validity of the study presented herein.

EXPERIMENTAL PROCEDURES

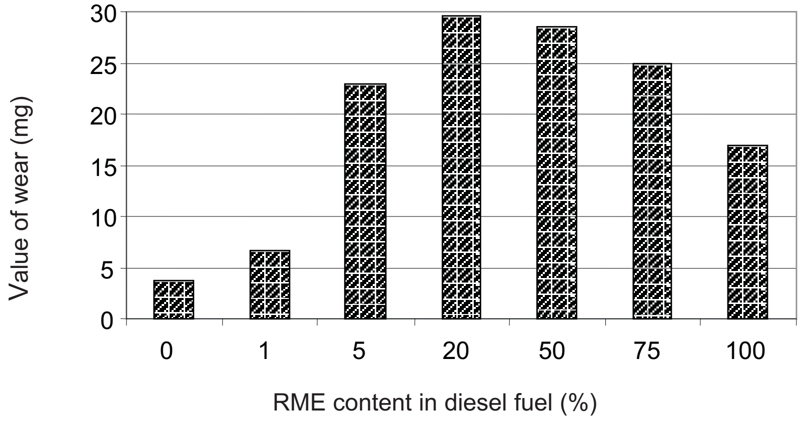
To carry out tribological studies of friction couple consisting of two different metals, it is necessary to apply a suitably prepared test station. To do that, the T 05 friction machine was used, whose modified design permits testing of samples created from different kinds of structural materials. The tribological experiments consisted in pressing a static aluminium sample in the form of a roller against a rotating steel ring partly immersed in the fuel examined. The samples were made of AK 9 (AlSi9Mg) aluminium, in the form of rollers with diameter Ø = 10 mm. The counter sample was a ring with diameter Ø = 35 mm, made of bearing steel ŁH 15, with hardness of 60 HRC and friction surface roughness of Ra 16 μm. The axes of symmetry of the sample and the counter sample were set perpendicular to each other. Such an alignment allows point contact to be achieved between the two elements, which determines the appearance of boundary friction on the surface of the layer of adsorbed polar compounds. The rotating ring *ie* the counter sample, was partly immersed in the fuel tested, assuring continuous lubrication. The process of the experiment was based on the ASTM G 77 standard. Parameters adopted in the experiment included linear velocity of friction v equal to 1 m s^{-1}, sample load P equal to 228 N, and friction distance s equal to 3500 m. Eco diesel Plus F50, a diesel fuel commonly available in retail, was used in the investigation. It is a fuel for compression-ignition engines, meeting the European standard EN 590:2002. The fuel is characterized by a low content of sulphur (below 50 ppm) and lowered cold filter clogging temperature (-20ºC). The second fuel was methyl esters of colza oil (RME). The experiment included the use of both the fuels in their pure forms and as mixtures at volume to volume ratios of 1, 5, 20, 50 and 75% of RME in the diesel fuel. The lubricity values of the investigated fuels were evaluated as ability to counteract sample wear. The value of sample wear was determined by means of the gravimetric method, using an analytical balance with measuring accuracy of ±0.001 g. Three test replications were made for each of the fuel mixtures used, and the average value of wear was calculated (mg). Also, visual assessment of the wear surface was performed.

RESULTS

The experiments performed provided data which permitted graphic presentation of the process of wear with relation to the amount of RME addition to diesel fuel, as illustrated in Fig. 1.

As can be seen in the Fig. 1, the wear of the sample is greater in the whole range of RME supplement to diesel fuel than the wear when pure diesel fuel was used. However, it is not a linear relation. A sudden increase of the wear value is observed in the range from 0 to 5% of RME supplement. The highest value of wear, 29.5 mg, was recorded for the mixture with 20% RME supplement. With increase in the level of RME supplement, the value decreased to 17 mg for pure RME fuel. The lowest wear value was observed with the use of pure diesel fuel, reaching the value of only 3.7 mg, which gives evidence about the excellent anti-wear properties of that fuel. Compilation of average values of sample wear and the relative percentage increase of wear in relation to pure diesel fuel is presented in Table 1.

The estimated values of relative increase of wear precisely define the scale of these changes. RME supplement of 1% caused an increase of wear by about 81%, and 5% supplement of the esters resulted in an increase of wear by about



Fg. 1. Value of sample wear by weight in relation to RME content in diesel fuel.

Table 1. Relative increase of sample wear in relation to diesel fuel composition

Parameter	RME content in diesel fuel (%)						
	0	1	5	20	50	75	100
Average wear (mg)	3.7	6.7	23.0	29.5	28.5	25.0	17.0
Relative increase of sample wear (%)	0	81	521	692	670	576	359

521%. The biggest value of wear is about 692% greater than the wear observed with the use of pure diesel fuel. The lubricity test performed with the use of pure esters showed a relative increase of wear by about 359%.

In order to define the character of tribological reactions on the friction surface, the samples were subjected to visual estimation of the wear marks. Examples of images of wear marks acquired with the scanning method are presented in Fig. 2.

On the friction surface presented in Fig. 2a there are visible dark marks parallel to the direction of rotation of the steel ring. This indicates an intensive process of the tribological reactions on the friction surface connected with high persistence of adsorbed boundary layers. The small area of contact causes the appearance of numerous individual pressures with resultant local rise of temperature. There is also visible pitting of the material on the friction surface, which indicates the appearance of adhesive friction, consisting in the surface of the sample getting 'stuck' on that of the counter sample as a result of the local rise of temperature and pressures. In Fig. 2b there are visible marks of wear of the sample with the highest degree of wear. The friction surface is characterised by high smoothness, silver-white colour and mirror-like reflection. The reason for that kind of appearance is very weak adhesion of polar compounds to the metal surface, which allowed the metal of the sample to be machined by unevenness in the level of roughness of the counter sample (Guha and Roy Chowdhur, 1996; Lee *et al*., 1994). In Fig. 2c there are visible marks of sample wear with the use of pure esters. The lower level of wear indicates an anti-wear action of the boundary layers, however considerable individual pressures caused a rise of temperature in the contact area, which is evidenced by the tarnish of the surface (Bowden and Tabor, 1980; Hebda and Janecki, 1972; Laber and Laber, 1997; Vick *et al*., 2000; Yevtushenko *et al*., 1997).

DISCUSSION

Curvilinear course of wear value in the function of bio fuel content in diesel fuel is an effect of compound physico-chemical processes taking place within the friction area. A fundamental role in the process of wear is that of the addition of esters containing hydrocarbon compounds (OH) of a polar character to diesel fuel (containing a set of highly efficient oiliness improvers). Oiliness improvers contained in diesel fuel are derivatives of chlorine (Cl), phosphorus (P) or boron (B), and create metallic soaps on the surface of metal. Hydrocarbon compounds contained in the esters also possess the ability of adhesion to the surface layer of metals. Both mechanisms create a boundary layer that separates surfaces in frictional contact in a durable manner. The process of adhesion of OH compounds to aluminium is accompanied by surface oxidation. Aluminium oxides are probably less strongly bound with the deeper layer of non-oxidized aluminium than adsorbed hydrocarbon compounds on steel surface. As a consequence, gradual wearing off of the layer of aluminium oxides is caused by friction of the adsorbed layer against steel surface. Abrasive wear continues until the appearance of resistance equilibrium of that layer to pressure and the related friction forces which appear in that association. The above mechanism occurs in mixtures containing from 5 to 50 % (v/v) of RME in diesel fuel. Along with increase in the addition of esters to diesel fuel there is also an increase in the degree of coverage of the friction surface with adsorbed OH compounds which create a layer that is more compact and resistant to forces of friction. An important role in that mechanism of surface wear is also played by the difference in electro-negativity of the two metals, causing differentiation of adhesion forces (Peterson, 1997; Wiltord *et al*., 2006).

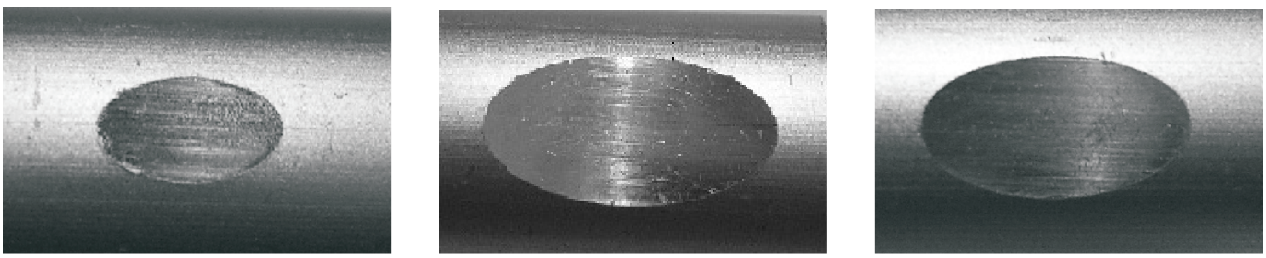


Fig. 2. Appearance of detritions in relation to content of esters in diesel fuel: a – 0, b – 20, and c – 100%.

CONCLUSIONS

1. Supplement of methyl esters of colza oil to diesel fuel causes significant increase of wear in the steel-aluminium friction couple.

2. The biggest value of wear was observed with the use of a mixture containing 20% of esters, constituting an increase of wear by about 692% in relation to pure diesel fuel.

3. The use the esters of colza oil in pure form or in mixtures with diesel fuel may lead to premature wear or failure of steel-aluminium friction couples in the fuel systems of Diesel engines.

REFERENCES

ASTM G, 77-98, **1998.** Standard test method for ranking resistance of materials to sliding wear using block-on-ring wear test. USA.

Baczewski K. and Kałdoński T., 2004. Fuels to Self – Acting Ignition Engines (in Polish). WKŁ Press, Warsaw, Poland.

Bocheński C., 2003. Biodiesel. Agricultural Fuel (in Polish). SGGW Press, Warsaw, Poland.

Bowden P. and Tabor D., 1980. Introduction to Trybology (in Polish). WNT Press, Warsaw, Poland.

Guha D. and Roy Chowdhur K., 1996. The effect of surface roughness on temperature at contact between sliding bodies. Wear, 197, 63-73.

Hebda M. and Janecki J., 1972. Friction, Lubrication and Wear of Part of Machine (in Polish). WNT Press, Warsaw, Poland.

Knothe G. and Steidley K.R., 2005. Lubricity of components of biodiesel and petrodiesel. The oring of biodiesel lubricity. Energy and Fuels, 19, 1192-1200.

Laber S. and Laber A., 1997. Select tribology problems with antifriction nature (in Polish). Zielona Góra Polytechnics Press, Monography, 85, Zielona Góra, Poland.

Lee K.S., Chen Y.M., and Dally J.M., 1994. A study of transitional friction behaviour at scaled micro contacts. Wear, 172, 99-105.

Majzner M., Kajdas C., and Okulicz W., 1998. Problems with lubricating of fuel oil of new generation (in Polish). Tribologia, 2, 109-129.

Peterson M.B., 1967. Mechanism of Wear. ASTM Press, New York, USA.

Vick B., Furey M.J., and Iskandar K., 2000. Theoretical surface temperatures generated from sliding contact of pure metallic elements. Tribology Int., 33, 265-271.

Wei D. and Spikes H.A., 1986. The lubricity of diesel fuels. Wear, 111, 217-235.

Wiltord F., Martin J.M., Le Mogne T., Jarnis F., Querry M., and Vergne P., 2006. Reaction mechanisms of alcohols on aluminium surface. Tribologia, 6, 7-20.

Yevtushenko A.A., Ivanyk E.G., and Ukhanska O.M., 1997. Transient temperature of local moving areas of sliding contact. Tribology Int., 30, 209-214.