Advances in Science and Technology Research Journal
Volume 8, No. 21, March 2014, pp. 54–57
DOI: 10.12913/22998624.1091879

Research Article

IMPACT OF ACID NUMBER OF FUELS ON THE WEAR PROCESS OF APPARATUS FOR FUEL INJECTION IN DIESEL ENGINES

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Received: 2013.12.17
Accepted: 2014.02.04
Published: 2014.03.05

ABSTRACT
Fuels used for diesel engines besides their main function of energy supply act as a lubricant. In this context the most important task is lubrication of precision pairs injection equipment. In this paper lubricating properties of rapeseed oil esters and camelina esters have been compared. Dependency of the electrical resistance and friction coefficient of the lubrication surface using different types of fuel was analyzed. It was stated, that the highest electrical resistance occurs when lubrication is done with diesel fuel, whereas the friction coefficient is the lowest and it occurs at lubrication with camellia esters.

Key words: biofuel, acid number, lubricity, injection apparatus, diesel engine.

INTRODUCTION

European Union obliged member countries to use liquid biofuels to supply traction engines in road transport. The main purpose of such an approach is reduction of crude oil consumption and reduction of greenhouse gases emission. In Europe and Poland, due to climatic and agronomic aspects, the most commonly used liquid biofuels are rapeseed oil methyl esters, and their mixtures with diesel.

A wider use of plant origined fuels reflects the emergence of controversial statements on their impact on the technical condition of engines. The largest differences refer to changes in viscosity and fuel behaviour at low temperatures. Especially important parameter is viscosity, which determines the quality of fuel atomization, sealing quality and lubrication of precision pair. Tribological processes are one of the main causes of operational wear of injection in diesel engines apparatus. In diesel engines fuel is not only an energetic medium, but also is a lubricant for injection system components. As a lubricant, fuel should have appropriate viscosity and lubricity. Fuel lubricity should not be either too high, due to the fact that it inhibits injection process, or too low due to the conditions of lubricating oil film formation.

Wear evaluation and repair of precision pairs piston – cylinder is difficult, requires good knowledge of the construction and operation of the fuel apparatus and large experience in processing technology of cooperating components. Wear studies of the precisely performed kinematic pairs of the injection pump requiring dismantling the pump, interfere operation of the matched pairs and limit the possibility of accurate wear forecast of the pumping sections. Precision pairs stand out from other subsystems of fuel apparatus with very precise performance and small clearances, as these are individually fitted components.

In technique the main lines of action to minimize wear are include modification of operating surfaces, most commonly by hardening the top surface, using lubricants to replace dry friction to fluid friction.

A hard surface of the element is subject to slower attriction, while lubricated surfaces are not subject to wear if a lubricant film is generated between them or the friction occurs between the surfaces covered with boundary layer of lubricant.

The boundary layer strongly related to base is generated by adhesion forces due to molecular interaction of atoms on the element surface with lubricants molecules. Polar structure of lubricating molecules favours formation of boundary layer. In diesel engines fuel is the only lubricating source of the precisely fitted components of the injection system. Thus, fuel lubricity is of high importance, which specifies its ability to form boundry layer strongly associated with lubricated surface [4].

From the chemical point of view this layer consists of hydrocarbon chains attached to clean metal surface with polar carboxyl group. This group is specific to carboxyl acids – thus acidification of fuel improves fuels' ability to produce the boundary layer. The boundary layer secures the surface against wear in case of lack of lubricant film. Application of new fuels, such as biofuels, always requires preliminary studies and engine studies. During engine operation, fuel system components are subject to complex impact of mechanical, chemical and thermal loads, resulting in functional changes of particular system components. In case of injection pumps, particularly intensive wear occurs between the working surface of cylinder and piston of pumping section and the surface of the cone shut-off valve forcing the pump. Abrasive effect of contaminants in fuel and active chemical compounds intensify wear process [3]. Majority of available publications state a beneficial tribological effect of biodiesel, however some studies have demonstrated some negative effects, which should be analysed [5].

PHYSICAL-CHEMICAL SPECIFICATION OF STUDIED FUELS

In the presented studies three types of fuel were used. The first one was a commonly available diesel produced by Orlen, meeting the requirements of PN-EN 590:2009 "Automotive fuels. Diesel. Requirements and test methods". A premise for diesel selection was the fact that it is the most commonly used fuel. As a second fuel rapeseed oil esters available at tank stations were used. The third type of fuel was camelina oil methyl esters, whose parameters were compared with requirements of ASTM D 6751-06b and PN-EN 14214:2009 standards "Automotive fuels. Fatty acid methyl esters (FAME) for diesel engines. Requirements and test methods". In the studies pure methyl esters were used, generated in estrification process, modifying acid number resulting in changed lubricity. Selected properties of fuels used for studies are given in Table 1.

STUDY METHODS

Wear studies were conducted by means of "Ball-on-disc" method. A tribometer was used (CSM Instruments). The studies were carried out at 10N load, test speed was set at 0.05 m/s, sliding distance between counterspecimen (6 mm diameter ball made of ŁH15 steel) and studied sample (30 mm diameter disc and 5 mm high made of ŁH15 steel) was 1000 m.

Samples were immersed in fuel. Three types of fuel dedicated to diesel engines were used: ON – diesel, EL – camelina esters with modified lubricity, BIO100 biofuel.

One of the methods to increase lubricity is increase of fuel acid number. Acid number is KOH milligrams required to neutralize fatty acids in 1 gram of fuel. In case of fuel and lubricating oils, organic acids content decides on containing carboxyl group. This group has a high affinity for metal and easily undergo chemisorption on their surface. Increased acid number is associated with larger number of absorbed hydrocarbon chains on the metal surface, which protects it against damage and reduces friction between lubricated surfaces. In the conducted studies oleic acid was used as a lubricity increasing agent. By adding

Table 1. Selected properties of diesel and methyl esters of camelina oil [1, 2]

Diesel	Density at 20°C [kg/dm^3]	Energy value [MJ/kg]	Kinematic viscosity at 40°C [mm^2/s]	Cetane number	Pour pint [°C]	Flash point [°C]
ON	0.84	42.7	2.0–4.5	50	Below –20	80
Methyl esters of camelina	0.88	37.5	5.18	52	–16	–
Methyl esters of rapeseed	0.88	38.0	5.20	45–59	–	approx. 170

oleic acid to camelina oil esters the acid number increases. The acid number of pure oleic acid $C_{18}H_{34}O_2$ is 198.69 [mg KOH/g]. The increased acidity is associated with increased lubricity due to above mentioned chemisorption phenomena [6],

In the studies three fuel samples were used, as well as biofuel based on methyl esters of camelina oil of different acid number:

- Diesel,
- Rapeseed oil esters meeting the requirements of PN-EN 14214:2009,
- Biofuel meeting the requirements of PN-EN 14214:2009 with acid number of 0.5 [mg KOH/g],
- Biofuel with acid number of 4.5 [mg KOH/g],
- Biofuel with acid number of 10 [mg KOH/g],
- Biofuel with acid number of 20 [mg KOH/g],
- Biofuel with acid number of 100 [mg KOH/g],
- Biofuel with acid number of 200 [mg KOH/g].

For each of the studied fuels friction momentum and electrical resistance distribution at the contact point with counterspecimen were determined.

TEST RESULTS OF FRICTION COEFFICIENT AND RESISTANCE

In samples with diesel as a lubricating agent the friction coefficient was $\mu = 0.11$. Fuels with higher friction coefficient can cause increased wear of injection engine apparatus than in case of the use of diesel as a fuel. Fuels with lower friction coefficient are more "friendly" to injection apparatus. Resistance measurements have not clearly demonstrated which type of fuel causes the lowest degradation of injection system.

CONCLUSION

Fuel in injection systems acts as a lubricating agent. Carboxyl acids content determines its lubricity, which easily undergoes chemisorption on the clean metal surface. Increasing their content by addition of oleic acid to the fuel (so called oleo) its lubricity can be influenced. However, the additional effect is increase of acid number – which value is limited by the standards. Acidity increase should be associated with the increase of lubricity and reduction of frictional resistance.

The conducted studies of the friction coefficient has demonstated that the lowest resistance occurs at lubrication with camelina esters with acid number of 200, followed by esters with 0.5 acid number and finally esters with 4.5 acid number. Listed camelina esters proved to be better than esters with higher acidity e.g. 10, 20 and 100. The obtained results confirmed relationships arising from the theory.

Electrical resistance of the lubricated tribological contact is usually proportional to the thickness of lubricating film, thus inversely proportional to friction coefficient value. The conducted studies have not confirmed the above relationship. Theoretically, the highest resistance and the thickest oil film should be visible at tribological contact lubrication with camelina esters of 200 acid number. However, studies have shown that theoretically the highest resistance and the thickest oil film occurs when lubrication is done with diesel fuel. This means lack of correlation between oil film thickness represented by electrical resistance and friction represented by friction coefficient.

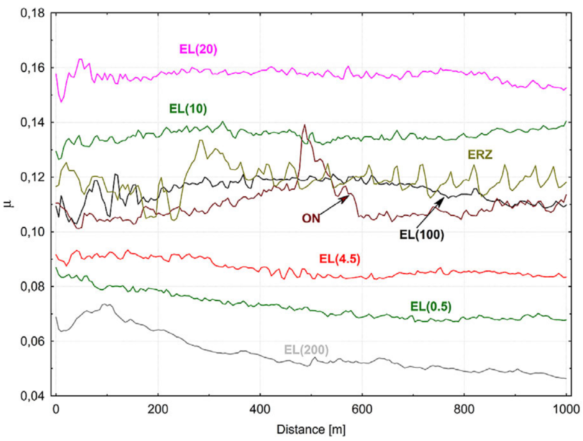

Fig. 1. Comparison of friction coefficient for the studied fuels

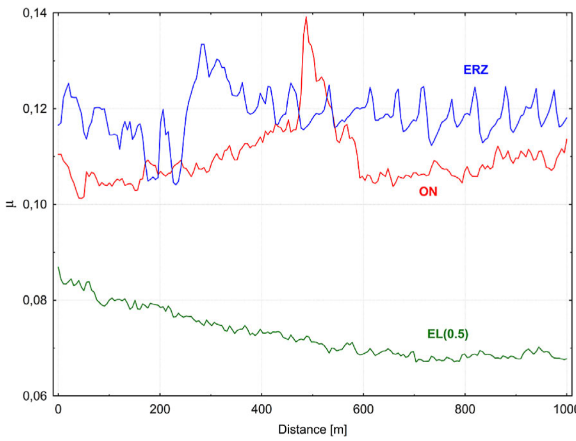

Fig. 2. Friction coefficient for fuels fulfilling requirement of standards for fuels

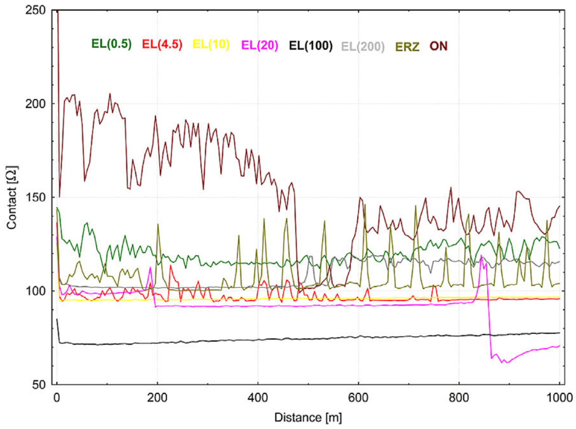

Fig. 3. Electrical resistance of the studied fuels at the contact point between specimen and counterspecimen

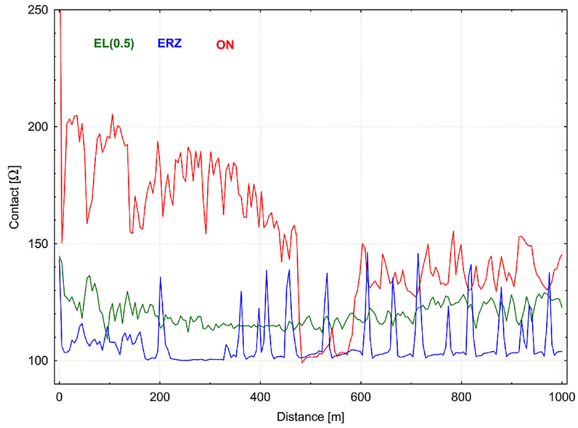

Fig. 4. Electrical resistance for fuels fulfilling requirements of standards for fuels

Due to the observed discrepancies between theoretical expectancies and obtained results, further studies aiming at clarifying observed relationships should be conducted.

REFERENCES

1. Gil L.: Badania zużycia tribologicznego elementów układu wtryskowego silnika o zapłonie samoczynnym zasilanego olejami roślinnymi. Rozprawa doktorska. Lublin 2010.
2. Lnianka, czyli lepszy rydz..., Wiadomości Rolnicze Polska, Wrzesień 2006.
3. Paluch R.: Wpływ ekologicznego oleju napędowego na niektóre parametry pracy silnika o zapłonie samoczynnym oraz zużycie elementów aparatury paliwowej. Rozprawa doktorska, Politechnika Lubelska, Lublin 2001.
4. Szczerek M., Tuszyński W.: Badania tribologiczne. Zacieranie, Wydawnictwo i Zakład Poligrafii Instytutu Technologii Eksploatacji, Radom 2000.
5. Tandon A., Kumar A., Mondal P., Vijay P., Bhangale U. D., Tyagi D.: Tribological Issues Related to the Useof Biofuels: A New Environmental Challenge, British Journal of Environment & Climate Change, 1(2), 2011: 28-43.
6. Gil L., Ignaciuk P.: Wpływ liczby kwasowej na smarność biopaliw. Postępy Nauki i Techniki, nr 11, 2011.