TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11, 415–421

THE INVESTIGATIONS OF THE INFLUENCE OF FUEL CONSUMPTION ON THE CHANGES OF SELECTED PARAMETERS OF THE LUBRICANT IN DIESEL ENGINES

Piotr Wanke

Warsaw University of Technology
Faculty of Civil Engineering, Mechanics and Petrochemistry
Department of Mechanical Systems Engineering and Automation
Address: Jachowicza 2/4, 09 – 402 Płock, Poland
e-mail: pwanke@pw.plock.pl

Summary. The paper presents the results of comparative investigations of changes in dynamic viscosity and dielectric constant of the lubricant in diesel engines fueled with Ekodiesel Plus 50B and Ekoterm Plus under real operating conditions.

Keywords: diesel fuels, engine lubricants, dynamic viscosity, dielectric constant.

INTRODUCTION

The real operating conditions of kinematic pairs in diesel engines (CI) depend on a variety of factors. The possibilities of occurrence of excess loads, high air dustiness, unprofessional and irregular maintenance, failure to use fuels to applicable standards (use of cheaper replacements) and fuels recommended by the manufacturers can result in unpredictable changes in the lubricant properties in the oil ducts. The design requirements, technologies of manufacturing of materials and parts in the kinematic pairs as well as mutual tribological relations during operation – much dependent on the quality of the applied lubricants and fuels – determine the course of the abrasive loss process in the said kinematic pairs of diesel engines and self-propelled machinery [Wanke, Koniuszy 2009, Wanke 2010]. The most difficult to define are the changes in the lubricating conditions in the slide areas of critical pairs related to a continuous deterioration of the rheological and qualitative parameters of the engine lubricants, resulting from the dissolution and dissipation of pollutants as well as fuel leaks through the piston rings [Szczerek, Wiśniewski 2000]. That is why in day-to-day operation the changes in the properties of the engine lubricant should be monitored between the scheduled maintenance inspections. The intervals recommended by the manufacturers due to various operating conditions are not always necessary to apply. Through a realization of periodic diagnostics of selected lubricant parameters for given operating conditions we can determine new oil change criteria, which is economically justifiable – particularly in professional applications. For central lubrication systems an appropriate selection of engine lubricant (particularly its properties and parameters) for the actual operating conditions can have a decisive influence on the optimization of the durability potential of the whole power train [Wajand J. A., Wajand J. T. 2000, Jakóbiec 2001 a, b, Olszewski i in. 2004, Bocheński 2005].

One of the more important issues in recent years in the field of durability optimization and reliability maximization in diesel engines in operation – discussed by authors of many publications – has been the use of fuels compliant with the manufacturer specifications and applicable standards [Mucha 2000, Oleksiak 2001 a, b, Baczewski K., Kałdoński T. 2004, PN-EN 590:2006]. In older generation of engines – engines of a lower fuel system sensitivity to the quality of fuel – very often different replacement fuels were used of unpredictable impact on the changes of the quality of the engine lubricant, thus on the durability and reliability of the engine [Kowalski 2006].

In relation to the presented conditions the authors, in the comparative tests, have undertaken to explain whether the amount of used fuel influences the rheological properties of the diesel engine lubricant (farm tractors) under real operating conditions. The authors particularly attempted to explain whether the observed changes of the selected engine lubricant properties can lead to a modification of the recommended service interval plan and, in extreme cases, whether they can lead to pathology in the wear of the critical friction pairs particularly those operating under slide friction.

The here presented results are a second part of the earlier publication of the author [Wanke 2010] and were collected simultaneously in the same field experiment under real operating conditions of the tractors.

RESEARCH METHODOLOGY

In the operational comparative investigations the authors tested two Ursus 1614 farm tractors manufactured in the years 1992÷1993 fitted with the Z 8602.1 engines after a rebuild performed in the beginning of 2006 before the start of the agricultural season. The tests were carried out in the agricultural season 2008 from 3 March to 6 December. The initial mileage of the first tractor marked A (fueled with Ekodiesel Plus 50B – diesel oil) equaled to 689,4 motor hours (mth) and the second marked B (fueled with Ekoterm Plus – heating oil) 703,6 motor hours counting from the engine rebuild. Directly prior to the initiation of the tests the engines were filled with the oil of the same grade SAE 15W/40, API CG-4, ACEA 96 E2/B2/A2 [Podniało 2002] and a diagnostics was performed according to the manual. Based on the obtained results of the inspection the engines were deemed parametrically acceptable – technically operative [URSUS 1614 Wheeled Farm Tractors 1992].

The monitored tractors belonged to one owner and were operated in the same farm simultaneously on the same fields at the same time adequately to their tractive effort for works related to soil cultivation, fertilization and crops transportation. Based on the performed diagnostics and analysis of the conditions it was assumed that both tractors were in a similar initial state and operated under similar operating conditions, which makes the test results comparable.

The oil samples for the comparative tests were taken according to a preset procedure – the same for each of the operated tractors. The first sample – the base sample was taken from the packaging when the oil was delivered to the workshop. The second one was taken directly upon finishing of the first day of operation. Then, the oil sample was taken regularly approximately every 1000 dm^3 of used fuel until the oil change. Each of the samples was marked. The oil samples were taken through the dipstick slot with the use of a syringe and a hose of the capacity of $50 \cdot 10^{-6}$ m^3, accuracy $\pm 5 \cdot 10^{-7}$ m^3, directly upon the finishing of the tractor operation. Immediately after the taking of the sample the syringe and the hose were thoroughly cleaned in a thinner and dried. The oil attrition was topped up. In the period of the experiment the amount of consumed fuel was recorded from the indications of the flow meters with the accuracy of $\pm 10^{-3}$ m^3.

For each of the taken samples the dynamic viscosity and the dielectric constant were measured three times in a steady temperature of T = 293 K and then the average values and standard deviations were calculated. For the marking of the viscosity a digital rotational viscosity meter was used – Brookfield DV-II+ with an ultra thermostatic chamber controlled by a PC computer with Rheocalc 32 installed. The measurement was carried out according to the [PN-EN ISO 3104:2004] standard and the recommendations of the manufacturers of the viscosity meter with the accuracy $\pm 10^{-2}$ mPa·s [Brookfield DV-II+ User Manual 2008]. For the determining of the changes in the quality of the oil a Lubrisensor device was used that, thanks to the absolute changes in the value of the dielectric constant (accuracy $\pm 10^{-1}$), enables detection of 3 groups of operational pollutants of the engine oil (group I – oxides and sediments, dirt, products of fuel combustion, acids; group II – water, coolant, metal parts; group III – fuel). The dielectric constant grows or lowers proportionally to the changes in the concentration of the pollutants present in the oil. The direction of the sway of the indicator towards „+" or „–" and the value of the indication determined the group of the pollutants and their amount. The evaluation of the condition of the tested oil consisted in calibrating of the device against a reference sample (fresh oil) and measuring of the changes of the dielectric constant for the tested samples taken from the engine [Lubrisensor User Manual 2000, Olszewski 2001]. The obtained results of the comparative tests were then correlatively and regressively analyzed on the significance level of $\alpha = 0.05$.

DISCUSSION OF THE TEST RESULTS

Based on the statistical analysis of the results a significant impact (significance level of α = 0,05) was observed of the amount and quality of the used fuel on the changes of the rheological and quality parameters of the engine lubricant of the grade SAE 15W/40 API CG-4. A very strong positive (directly proportional dependence of the dielectric constant – Fig. 2) and negative correlation (indirectly proportional dependence of the dynamic viscosity – Fig. 1) has been observed as a function of the amount of the used fuel and the multiple correlation – type R(z/xy) (Fig. 3). The comparison of the coefficients of the directions of the regression lines indicates that the unit drop of the dynamic viscosity of the lubricant – grade SAE 15W/40 API CG-4 in the engine fueled with diesel oil (Fig. 1, straight line) is approximately 10% lower than in a comparable engine fueled with heating oil (Fig. 1, dotted line). In the case of the relative changes in the dielectric constant it has been observed that the unit increment of the analyzed parameter is approximately 33% higher than in the case of engine B fueled with heating oil (Fig. 2, dotted line).

During the comparative operational measurements of the changes in the quality of the engine oils with the use of Lubrisensor in the case of all samples taken directly from the oil sump in the tested range of operation only the pollutants from group I have been observed. The pollutants from groups II and III (water, coolant, metal particles and fuel) were not detected by the device. This could confirm the earlier formulated assumption (at the beginning of the comparative investigations) that the engines were fully operational parametrically upon inspection as per the recommendation of the manufacturer. An important effect of the performed tests is the increment of the dielectric constant – clearly seen in figures 2 and 3 (as compared with the reference oil) only in the first oil samples

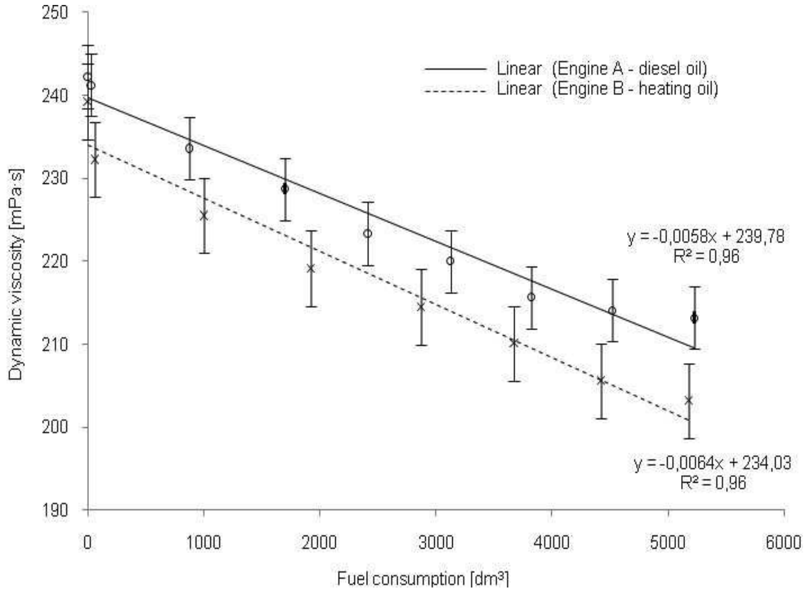

Fig. 1. The comparison of the regression lines of the changes in the dynamic viscosity of the engine oil – grade SAE 15W/40 API CG-4 as a function of fuel consumption (constant measurement temperature T = 293 K)

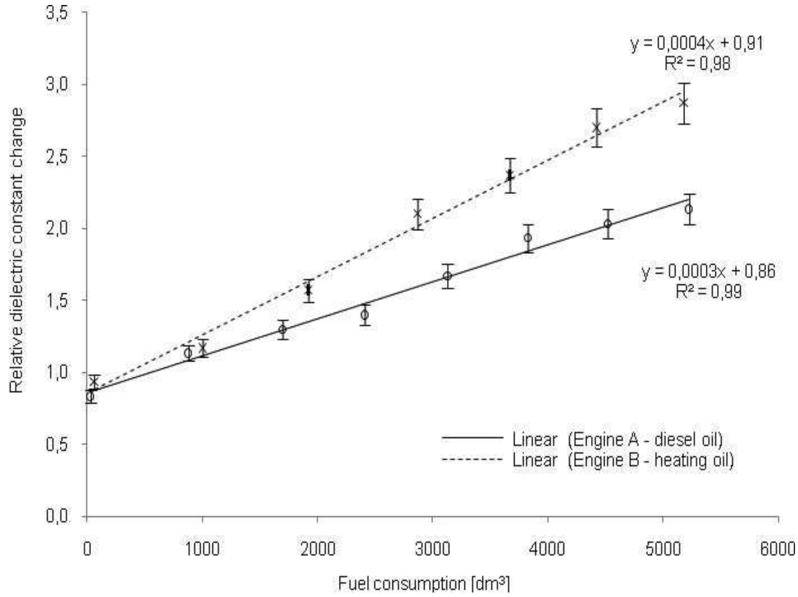

Fig. 2. The comparison of the regression lines of the relative changes of the dielectric constant of the engine oil – grade SAE 15W/40 API CG-4 as a function of fuel consumption (constant measurement temperature T = 293 K)

taken from the engines upon consuming of 29 dm^3 (tractor A) and 60 dm^3 (tractor B) of fuel respectively at a simultaneous drop in the dynamic viscosity of up to 17% when fueled with Ekoterm Plus (fig. 3). Such a significant change after only one day of operation may indicate an excess amount of pollutants (carbon sediments, tar) inside the engine and oil ducts and may necessitate engine flushing at the nearest oil change.

The results shown in Fig. 1, 2 and 3 of periodic monitoring of the changes of the selected rheological and qualitative properties of the engine oil - grade SAE 15W/40 API CG-4 as a function of fuel consumption realized under real operating conditions of the farm tractors constituted a basis for the extension of the oil change interval recommended by the manufacturer (recommended 200 mth of operation) [URSUS 1614 Wheeled Farm Tractors 1992]. Throughout the whole agricultural season (field works and transport) at the fuel consumption of 5226 dm^3 – for engine A fueled with Ekodiesel Plus 50B – and 5180 dm^3 for engine B fueled with Ekoterm Plus the excess of the admissible changes of the dynamic viscosity and the dielectric constant was not observed against fresh oil despite the extension of the oil change interval by approximately 80% and 60% respectively [Wanke 2010].

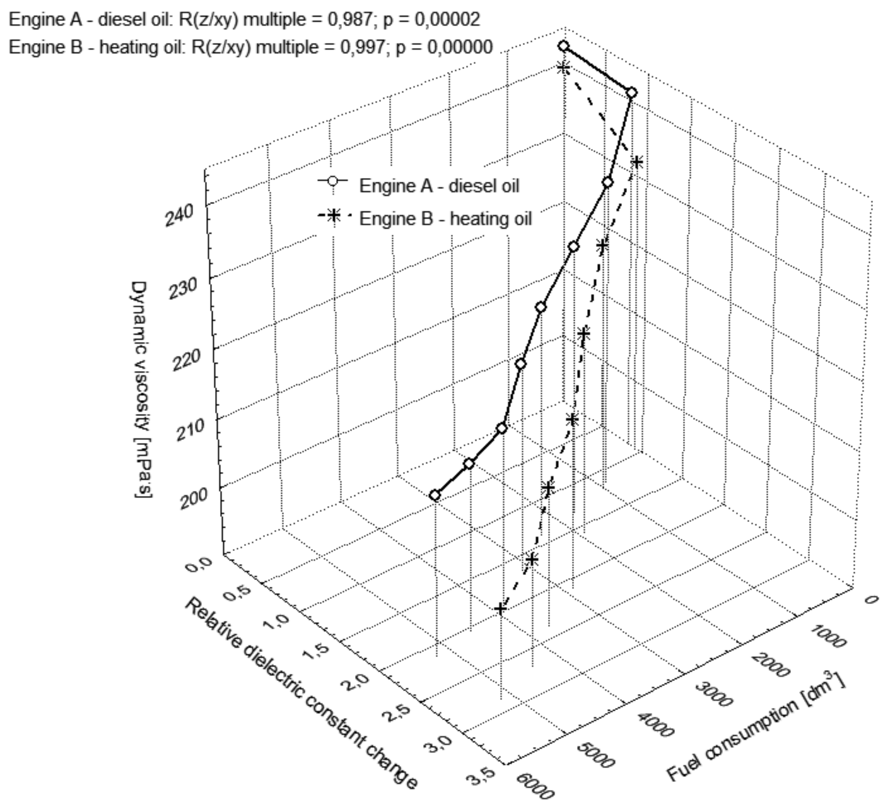

Fig. 3. The graph of the spread of the values with the lines of the dynamic viscosity changes and the dielectric constant of the engine oil – grade SAE 15W/40 API CG-4 as a function of fuel consumption (multiple correlation indicators included of constant temperature of T = 293 K)

Based on the discussed nature of the changes of the dynamic viscosity and the dielectric constant of the engine oil – grade SAE 15W/40 API CG-4 as a function of quantity (also depending on the quality) of the used fuel a supposition was formulated of a possibility of a significant extension of the oil change intervals for the Z 8602.1 engines until the boundary values are reached as defined in the change ±25% (dynamic viscosity) [Bocheński 2005] and 3.5÷4.0 (dielectric constant) [Sobańska-Górska, Zajkowski 1995].

CONCLUSIONS

1. The Z 8602.1 engine fueling with Ekoterm Plus accelerates the unit growth of the dielectric constant by approximately 33% and results in an approximately 10% faster drop in the dynamic viscosity of the engine oil – grade SAE 15W/40 API CG-4 as a function of the amount of consumed fuel as compared to the fueling with Ekodiesel Plus 50B. This indicates a significant acceleration of the engine oil parameters deterioration that may lead to the deterioration of the lubricating conditions and an accelerated wear of the friction pairs through the reduction of anti wear oil properties used in the friction surfaces of the kinematic pairs in the engine.
2. Unit changes in the values of the dynamic viscosity and the dielectric constant in the compared samples of the engine oil are very strongly correlated (on the significance level of $\alpha = 0.05$) with the amount and quality of the consumed fuel.
3. Periodic monitoring of the engine oil conditions in the Z 8602.1 engines – in operational conditions – allows for an extension of the oil change interval depending on the local operating conditions measured by the amount of fuel used during an operation.

REFERENCES

1. Baczewski K., Kałdoński T. 2004: Paliwa do silników o zapłonie samoczynnym. WKŁ, Warszawa.
2. Bocheński C. 2005: Paliwa i oleje smarujące w rolnictwie. Wydawnictwo SGGW, Warszawa.
3. Instrukcja obsługi. Lepkościomierz cyfrowy Brookfield DV–II+, 2008.
4. Instrukcja obsługi. Lubrisensor, 2000.
5. Instrukcja obsługi. Kołowe ciągniki rolnicze URSUS 912, 914, 1012, 1014, 1222, 1224, 1614. Wydawnictwo ZSL, Warszawa 1992.
6. Jakóbiec J. 2001 a: Zmiany właściwości użytkowych olejów silnikowych w warunkach eksploatacji (cz. 1). Paliwa Oleje i Smary w Eksploatacji, nr 83, 25–28.
7. Jakóbiec J. 2001 b: Zmiany właściwości użytkowych olejów silnikowych w warunkach eksploatacji (cz. 2). Paliwa Oleje i Smary w Eksploatacji, nr 84, 30–32.
8. Kiernicki Z. 2010: Some properties of the diesel fuelled with the fuel from plastic waste. Teka Kom. Mot. Energ. Roln. – OL PAN, v. 10, 153–162.
9. Kowalski K. 2006: Użytkowanie pojazdów wojskowych w warunkach niedoboru paliw bazowych. Eksploatacja i Niezawodność, nr 4, 16–21
10. Mucha J. 2000: Jakość oleju napędowego a eksploatacja silnika. Paliwa Oleje i Smary w Eksploatacji, nr 79, 36–38.
11. Oleksiak S. 2001 a: Ocena smarności olejów napędowych (cz. 1). Paliwa Oleje i Smary w Eksploatacji, nr 88, 36–38.

12. Oleksiak S. 2001 b: Ocena smarności olejów napędowych (cz. 2). Paliwa Oleje i Smary w Eksploatacji, nr 89, 35–38.
13. Olszewski W. 2001: Możliwość oceny stanu jakości oleju silnikowego podczas eksploatacji za pomocą pomiaru własności dielektrycznych. Journal of Kones. Combustion Engines, nr 3–4, 95–101.
14. Olszewski W., Maciąg A., Janik R. 2004: Ocena wpływu czasu eksploatacji na właściwości użytkowe olejów silnikowych. Problemy Eksploatacji nr 1, Instytut Technologii Eksploatacji, Radom.
15. Podniało A. 2002: Nowe specyfikacje olejów silnikowych. Paliwa, Oleje i Smary w Eksploatacji, nr 100, 38 – 40.
16. Sobańska-Górska K., Zajkowski R. 1995: Eksploatacyjna weryfikacja przydatności przyrządu Lubrisensor do szybkiego określania optymalnego czasu pracy oleju silnikowego. Instytut Transportu Samochodowego, Warszawa.
17. Szczerek M., Wiśniewski M. 2000: Trybologia i trybotechnika. Wydawnictwo Instytutu Technologii Eksploatacji, Radom.
18. Wajand J.A., Wajand J.T. 2000: Tłokowe silniki spalinowe średnio- i szybkoobrotowe. WNT, Warszawa.
19. Wanke P., Koniuszy A. 2009: An analysis of wear of slide pairs lubricated by class CC 30 lubricants mixed with diesel fuels. Teka Kom. Mot. Energ. Roln. – OL PAN, v. 9, 370–376.
20. Wanke P. 2010: A study on fuel quality impact on the changes of selected lubricant parameters in self-ignition engines. Teka Kom. Mot. Energ. Roln. – OL PAN, v. 10, 2010, 503–508.
21. PN-EN ISO 3104:2004: Przetwory naftowe. Ciecze przezroczyste i nieprzezroczyste. Oznaczanie lepkości kinematycznej i obliczanie lepkości dynamicznej.
22. PN-EN 590:2006: Paliwa do pojazdów samochodowych. Oleje napędowe. Wymagania i metody badań.

BADANIA WPŁYWU ZUŻYCIA PALIWA NA ZMIANY WYBRANYCH PARAMETRÓW OLEJU SMARNEGO W SILNIKACH Z ZAPŁONEM SAMOCZYNNYM

Streszczenie. W pracy omówiono wyniki badań porównawczych zmian lepkości dynamicznej i stałej dielektrycznej oleju smarnego w funkcji zużycia paliwa, w silnikach z zapłonem samoczynnym, zasilanych paliwem Ekodiesel Plus 50B i Ekoterm Plus w rzeczywistych warunkach eksploatacji.

Słowa kluczowe: paliwa do silników z zapłonem samoczynnym, oleje silnikowe, lepkość dynamiczna, stała dielektryczna.