TEKA Kom. Mot. Energ. Roln. – OL PAN, 2010, 10, 503–508

A STUDY ON FUEL QUALITY IMPACT ON THE CHANGES OF SELECTED LUBRICANT PARAMETERS IN SELF-IGNITION ENGINES

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Summary. The paper includes discussion of the comparative studies describing the changes of dynamic viscosity and dielectric constant of the lubricant oil in agricultural tractor self-ignition engines fuelled by Ekodiesel Plus 50B and Ekoterm Plus under real operating conditions.

Key words: self-ignition engine fuels, engine lubricants, dynamic viscosity, dielectric constant

INTRODUCTION

The actual operating durability of sliding pairs commonly called critical friction nodes in agricultural vehicles with self-ignition engines depends on many factors. The structural form, technological history of the materials and parts, friction conditions, lubricant and fuel quality, the dynamically varying operation process determine the intensity of wear in kinematic slide pairs of the self-ignition engines of tractors and mobile farming machines. The pathological development of the loss process in the critical node areas is mainly caused by the changes of lubrication conditions, related to permanent deterioration of the rheological and qualitative parameters of the lubricant oils. Their appropriate adaptation to the real conditions of the working process performance may be decisive in the optimization of the potential structural durability resource of the whole drive unit [Szczerek, Wiśniewski 2000, Jakóbiec 2001 a, b, Olszewski et al. 2004]

Adverse working conditions, high level of dust in the air, unprofessional operators, the use of lower quality fuels may cause the loss of lubricant oil properties in the engine. Unfortunately, these are very often the typical conditions of operating farm tractors and vehicles in Poland. According to numerous authors, one of the more important issues is the use of engine fuels compliant with the manufacturers' requirements and applicable standards [Mucha 2000, Wajand J. A., Wajand J. T. 2000, Baczewski K., Kałdoński T. 2004, Bocheński 2005, PN-EN 590:2006]. The users of older generation tractors, with lower sensitivity of the fuel feed systems to the quality of the fuel used, often select to use "cheaper substitutes" – boat fuels, vegetable or heating oils. In most cases the first symptom of such operation are defects and failures of the injection system. However, it is much more difficult to the determine the impact of such "substitutes" on the engine lubricant oil quality changes that may lead to reduction of the pre-repair run and in extreme cases to the development of pathological wear processes in the critical friction node areas – particularly cooperating under slide friction conditions [Oleksiak 2001 a, b, Wanke 2003, Wanke, Koniuszy 2009, Kowalski 2006].

In relation to the conditions presented herein, an attempt was made to explain the impact of the quality of the fuel used in self-ignition engines on the changes of the dielectric constant and dynamic viscosity of the lubricant oil observed under real operating conditions of farm tractors.

TESTING METHODS

To carry out the operating comparative tests, two Ursus 1614 farm tractors were selected, manufactured in 1992÷1993, powered by Z 8602.1 engines after an engine rebuild made in early 2006, before start of the agricultural technological season. The tests were made in the 2008 agricultural technological season, between 3rd March and 6th December. The initial run of the first tractor marked with the symbol A (fuelled by Ekodiesel Plus 50B – heavy oil) was equal to 689,4 motohours (mth), while that of the other one marked B (fuelled by Ekoterm Plus – heating oil) - 703,6 mth from the rebuild. Right before the test start, the engine lubrication systems were filled with the same oil class SAE 15W/40, API CG-4, ACEA 96 E2/B2/A2 [Podniało 2002] and diagnostics of the condition was carried out following the user manual. In virtue of the control results obtained, the engines were recognized as parametrically capable – technically efficient [URSUS 1614 Wheeled Farm Tractors 1992].

The tractors monitored had one owner and were used on one farm, in the same fields parallel, simultaneously, in a typical manner as for their class of towing power, at work related to soil cultivation, plant fertilization and crop transportation. Based on the diagnostic procedures and analysis of the conditions presented, an assumption was made that both tractors were in similar initial state and were operated under approximately similar working process performance conditions, which allows the comparison of the test results obtained.

The oil used in the comparative tests was sampled according to the agreed procedure, identical for each of the tractors used. The first basic sample was taken during change of the oil from the package delivered to the workshop, the second – after the first working day. The following samples were taken ca. every 50 mth of the engine operation, until the next lubricant oil change. Each sample was labeled. The lubricant was taken from the engine through the oil level dipstick hole, by means of a syringe with a tube of $\pm 50 \cdot 10^{-6}$ m^3 capacity, with $\pm 5 \cdot 10^{-7}$ m^3 accuracy, directly after completion of the tractor's operation. The syringe and tube were thoroughly washed in a thinner and dried and the oil losses supplemented immediately after sampling. The number of mth worked was recorded during the experiment, following the odometer reading.

The dynamic viscosity and dielectric constant changes at fixed temperature of 293 K, were then measured 3 times for each sample and then averages and standard deviations were calculated. Viscosity was measured with the use of Brookfield DV-II+ rotational viscometer with ultrathermostat chamber, controlled by PC with Rheocalc 32 software. The measurement was carried out in compliance with [PN-EN ISO 3104:2004] and the viscometer manufacturer's indications with $\pm 10^{-2}$ mPa·s accuracy [Brookfield DV-II+ 2008 User Manual]. The qualitative changes in the lubricant oil were determined by means of Lubrisensor enabling the recognition of 3 groups of operating contamination of lubricant oil thanks to the measurement of relative changes of dielectric constant value (with $\pm 10^{-1}$ accuracy): (group I – oxides, sediments, dirt, fuel combustion products, acids, group II – water, coolant, metal particles; group III - fuel). The dielectric constant increases or decreases proportionally to the concentration of contaminants present in the lubricant oil. The direction of the indicator's inclination towards „+" or „–" and the indication value determine the group of contaminants and their quantity. The assessment of the oil tested consists in the calibration of the device on basic sample (fresh oil) and measurement of the value of dielectric constant changes for the tested samples taken from the engine [Lubrisensor 2000 User Manual, Olszewski 2001]. The results obtained were subjected to statistical analysis on the significance level $\alpha = 0,05$.

DISCUSSION OF THE TEST RESULTS

The test results were divided into two groups. The first group comprising the comparison of dynamic viscosity operating changes (fig. 1) and the second one illustrating the relative changes of the dielectric constant values (fig. 2) class SAE 15W/40 API CG-4 lubricant oil in operating time function, depending on the quality of fuel applied (tractor A – heavy oil, tractor B – heating oil).

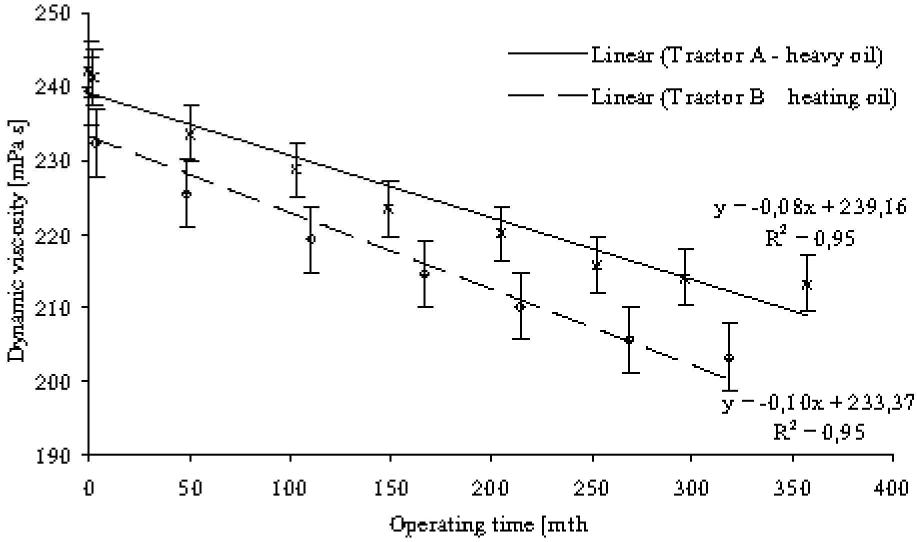

Fig. 1. Comparison of the regression line of dynamic viscosity changes in lubricant oil class SAE 15W/40 API CG-4 in the function of operating time of two tractors subjected to the operating tests

Based on the test result statistical analysis (the analysis of the variance and regression statistics), a significant impact ($\alpha = 0,05$) of the operating time and quality of the fuel used on selected rheological and qualitative changes of the lubricant oil class SAE 15W/40 API CG-4 was observed. The occurrence of a very strong positive correlation (direct proportionality to the dielectric constant – fig. 2) and negative (inverse proportionality to dynamic viscosity – fig. 1) were observed in the function of the operating time. The comparison of the directional coefficients of the regression lines indicates that the unit dynamic viscosity drop in lubricant oil class SAE 15W/40 API CG-4 in the operating time function (fig. 1), of the engine fuelled by heavy oil (continuous line) is by ca. 20% lower than of the engine fuelled by heating oil (dotted line). In case of relative dielectric constant changes, however, it was observed that the unit increase of the parameter analyzed is by ca. 75% higher in the case of tractor B fuelled by heavy oil (fig. 2, dotted line).

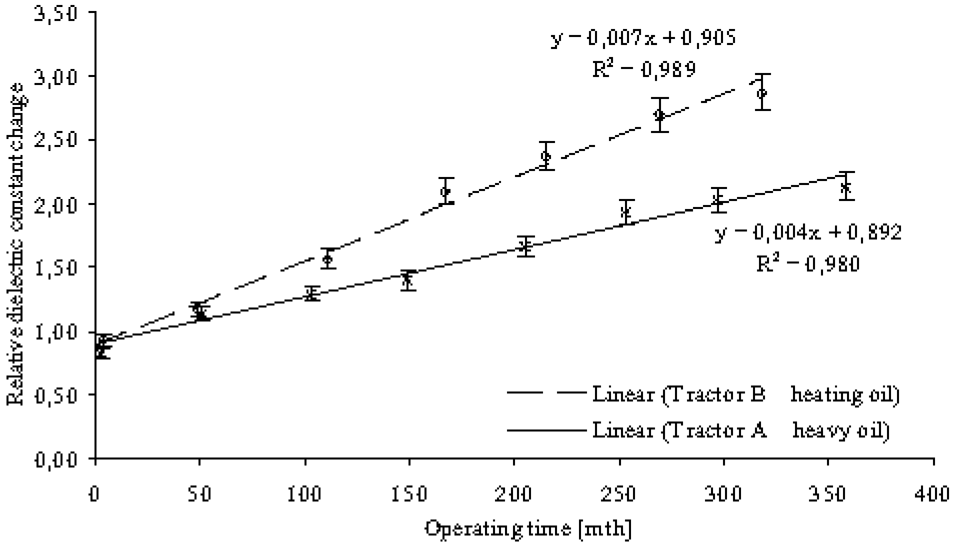

Fig. 2. The comparison of relative dielectric constant changes of class SAE 15W/40 API CG-4 lubricant oil in the function of two tractors' operating time under operating tests

During the comparative operating tests on the qualitative changes of lubricant oils made with the use of Lubrisensor, in the case of all the samples taken directly from the oil sump in the operating period tested, the group I contaminants only were detected. No group II and III contaminants (water, coolants, solid particles, fuel) in amounts detectably by the instrument were found. This can be confirmed by the assumption formulated earlier on the condition of full parametric usability of the engines, taken at the beginning of the comparative tests, upon diagnostic procedures made as indicated by the manufacturer. An important effect of the tests carried out is – as clearly seen in fig. 2 – the increase of the dielectric constant value (related to the basic oil) in the first samples of oils taken from the engines already, after 2,5 mth (tractor A) and 3,6 mth (tractor B) of operating time, respectively. The change so rapid during the first hours of operating time already – in the author's opinion – may prove the occurrence of excessive amount of contaminants (e.g. carbon deposits, sediments, sludge) in the internal spaces and oil ducts of the engines analyzed and indicate the necessity to wash the systems with the following oil change.

The results of period monitoring of the rheological and qualitative properties of lubricant oil class SAE 15W/40 API CG-4, illustrated in fig. 1 and 2 carried out under real operating conditions of the tractors were the basis for the extension of the interval between oil changes as compared to that suggested by the manufacturer, covering 200 mth of operation. Throughout the agricultural technical season of the field and transport work, from early spring until late autumn, with the runs coming up to 357,9 mth – for engine A fuelled by Ekodiesel Plus 50B – and 318,3 mth – for engine B fuelled by Ekoterm Plus – the boundary value of dynamic viscosity change and dielectric constant in relation to the basic oil was not exceeded, despite the significant extension of the operating time "between oil changes", by ca. 79% and ca. 59%, respectively.

Based on the discussed nature of changes of the dynamic viscosity and dielectric constant of lubricant oil class SAE 15W/40 API CG-4 in the function of operating time and depending on the type of fuel used, a presumption was formulated on the possibility of further extension of the tractor intervals "between the oil change", until the permitted values are reached, defined in the variability ranges of ±25% (dynamic viscosity) [Bocheński 2005] and 3,5÷4,0 (dielectric constant) [Sobańska-Górska, Zajkowski 1995]. The tests are continued in order to verify and detail the results and eliminate, if possible, any accidental errors.

CONCLUSIONS

1. Fuelling a self-ignition engine with Ekoterm Plus fuel accelerates the unit increase of the dielectric constant by ca 75% and causes faster dynamic viscosity decrease by ca 20% in lubricant oil class SAE 15W/40 API CG-4 in the operating time function as compared to the engine fuelled with Ekodiesel Plus 50B engine. This indicates a significant acceleration of the oil degradation under operation, which may lead to deterioration of the lubricating conditions and accelerated wear of the working surfaces through reduction of the anti-wear lubricant action on the top layer of the sliding friction nodes of the engine.
2. The intensity of the dynamic viscosity and dielectric constant changes in the samples compared of the tested lubricant oil is closely correlated with the quality of the used fuel and operating time under real conditions of performance in agriculture.
3. The use of higher quality oil (API CG-4) than the one indicated by the manufacturer (API CC) enables the extension of the time "between oil changes". The actual operating run of the tested oil was increased by 79% in tractor A (Ekodiesel Plus 50B) and 59% in tractor B (Ekoterm Plus), respectively and the values of the monitored parameters did not indicate the demand for oil change.

Based on the obtained comparison results, the observations were formulated that require further analysis:

- Further regular monitoring of the condition of the lubricant oil class SAE 15W/40 API CG-4 under operating conditions shall enable the presumable determination of a new range of admissible intervals between oil change, depending on the real necessities of the local working environment,
- In order to optimize the intervals „between the oil change" of new generation lubricant oils used in older self-ignition structures, tests on a wider statistical group of tractors should be made – it is necessary to select objects working under different conditions and with various loads and to determine the impact of particular operating factors on the intensity of rheological and qualitative parameter changes in the applied lubricant oils.
- An instrument to measure the dielectric constant changes may be useful in a prompt and easy assessment of the qualitative condition of the oil and indicate the necessity for oil change in tractors and farm vehicles.

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BADANIA WPŁYWU JAKOŚCI PALIWA NA ZMIANY WYBRANYCH PARAMETRÓW OLEJU SMARNEGO W SILNIKU Z ZAPŁONEM SAMOCZYNNYM

Streszczenie. W pracy omówiono wyniki badań porównawczych, opisujących zmiany lepkości dynamicznej i stałej dielektrycznej oleju smarnego w silnikach ciągników rolniczych z zapłonem samoczynnym, zasilanych paliwem Ekodiesel Plus 50B i Ekoterm Plus w rzeczywistych warun-kach eksploatacji.

Słowa kluczowe: paliwa do silników ZS, oleje silnikowe, lepkość dynamiczna, stała dielektryczna