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AN ANALYSIS OF WEAR OF SLIDE PAIRS LUBRICATED BY CLASS CC 30 LUBRICANTS MIXED WITH DIESEL FUELS

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Abstract. The paper presents the results of comparative laboratory tests describing the changes in the wear of samples made from steel type ŁH 15 operating in a steel to steel sliding pair in CC 30 oil bath lubrication with the addition of Ekodiesel Plus F50, Ekoterm and RME (2÷20)% by volume.

Keywords: sliding friction, wear, lubrication, diesel fuels.

INTRODUCTION

An effective operation of diesel engines in agricultural tractors and vehicles depends on the quality of fuel and the quality of lubrication in the critical friction nodes such as crankshaft bearings and piston-ring-cylinder assembly [Kazimierczyk 1996]. The lowest wear, commonly known as regular wear occurs for the friction pairs during fluid friction at hydrodynamic lubrication (and/or elastohydrodynamic friction) [Szczerek *et al.* 2000]. It is possible if there exists a required play in the kinematic pairs that determine the formation of the lubricating film under given conditions of viscous fluid flow (lubricant) – permanently separating the friction surfaces [Lawrowski 1996].

The necessary condition in the form of play in the engine slide bearings enabling the hydrodynamic lubricant uplift results in an admissible leakage in the lubricating systems. This is of particular importance in the case of the piston-ring-cylinder assembly as it results in the fuel getting to the sump and affects the rheological properties of the lubricant in all the centrally lubricated sliding nodes generally acknowledged as the "weak links" [Wajand J.A., Wajand J.T. 2000]. This may cause an intensification of the wear process, friction wear and adhesive wear in particular [Burakowski, Wierzchoń 1995], a deterioration of the reliability and shortening of the rebuild intervals caused by the accelerated depletion of the durability potential of the critical nodes [Żółtowski 1996]. Additionally, difficult to foresee consequences may also result from an application of fuels of different quality in engines not fully adapted to such fuels [Baczewski, Kałdoński 2004; Bocheński 2003; Majzner *et al.* 1998].

In relation to what was stated above, the authors have attempted to explain an influence of the addition of diesel oil, heater oil and RME to the engine lubricant on the wear of the steel parts operating in a steel to steel sliding pair.

TESTING METHODOLOGY

In the comparative wear tests (under sliding friction and concentrated linear contact) an oil bath lubrication type was applied with the CC 30 lubricant (according to API) and its mixtures containing 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, 20% of Ekodiesel Plus F50 (ON) diesel oil, heater oil Ekoterm (OO) and RME, respectively. The samples and the countersamples were made of steel type ŁH15 – in the condition after thermal hardening (60±3 HRC) and final polishing towards roughness class 8. The friction node was loaded through a static sample with clamping forces variable in time against a variable speed rotating countersample in the form of a ring (Fig. 1). Standardized test runs were performed on a friction machine - T 05 according to the standard ASTM G 77-98. The algorithm of the clamping force variability and the relative speeds in the contact area during a single test run were shown in Table 1. For each of the lubricating variant 4 test runs were realized under similar conditions.

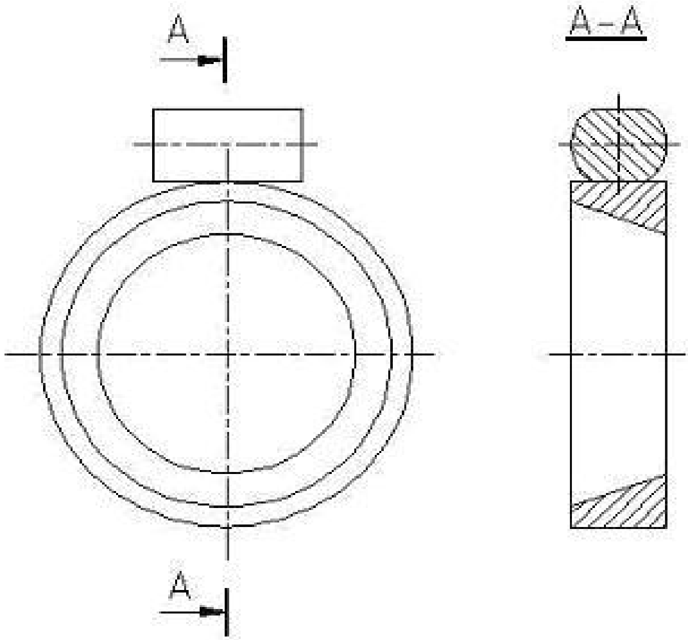

Fig. 1. Schematics of the friction node.

The tests of the sample wear were realized through measuring of the depth of the wear traces with an optimeter ($\pm 0{,}5 \cdot 10^{-6}$m accuracy) with SNAP LINE. Average wear values were computed (including standard deviation) expressed in a linear material decrement in the contact area for all the test runs in the lubrication variants under analysis. Additionally, measurements of the change in the roughness of the surface of the samples were made after the final polishing and on the wear traces (profilograph Hommelwerke T 1000E supporting TURBO DATAWIN according to the standard of PN-EN ISO 4287). All the samples and countersamples were degreased before the measurement. The obtained test results were subject to statistical analysis on the level of significance $\alpha = 0{,}05$.

Table 1. Algorithm of the clamping force variability and the relative speeds in the contact area during a single test run.

Load, P [N]	Relative speed in the contact area [$m \cdot s^{-1}$]	Time [s]
38,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
188,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
338,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
438,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
538,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
612,7	0,3	60
	0,6	60
	0,9	60
	1,2	60
	Total run time	1440

TEST RESULTS - DISCUSSION

The tests results were divided into two groups. The first comparing the sample wear depending on the percentage of the fuel content in the CC 30 oil (Fig. 2) and the second illustrating the changes of parameter R_a of the roughness profile of the surface in relation to the amount of fuel in the CC30 engine oil (Fig. 3).

The most advantageous course of the changes of the sample wear was obtained under the conditions of CC 30 oil lubrication with the addition of RME. In all the tested proportions of RME a reduction of wear was observed as opposed to the lubrication with pure engine oil. The highest (34% on average) reduction of the linear decrement of material in the contact area as compared to the lubrication of the base oil was observed for 10% content of the RME addition. Even in the case of the 20% content of RME in the engine oil the wear was still approximately 10% lower than for the lubrication of pure CC 30 engine oil (Fig. 2, broken line).

The changes in the characteristics of the wear of the samples when lubricated with a mixture of CC 30 engine oil and the addition of diesel oil and heater oil reached similar values in the performed tests with the statistical variation resulting from the assumed level of significance (Fig. 3, continuous line - diesel oil, dotted line - heater oil). The reduction (approximately by 10% in relation to the lubrication with the base oil) of the linear material decrement in the contact area was observed only at 2% content of diesel oil or heater oil. In the case of all the outstanding proportions of the lubricating mixtures the growing trend of the wear was observed, on average by approximately 45% (CC 30 and 20% diesel oil) and 55% (CC 30 and 20% of heater oil) increase in the linear material decrement in the contact areas as opposed to the lubrication with the base oil.

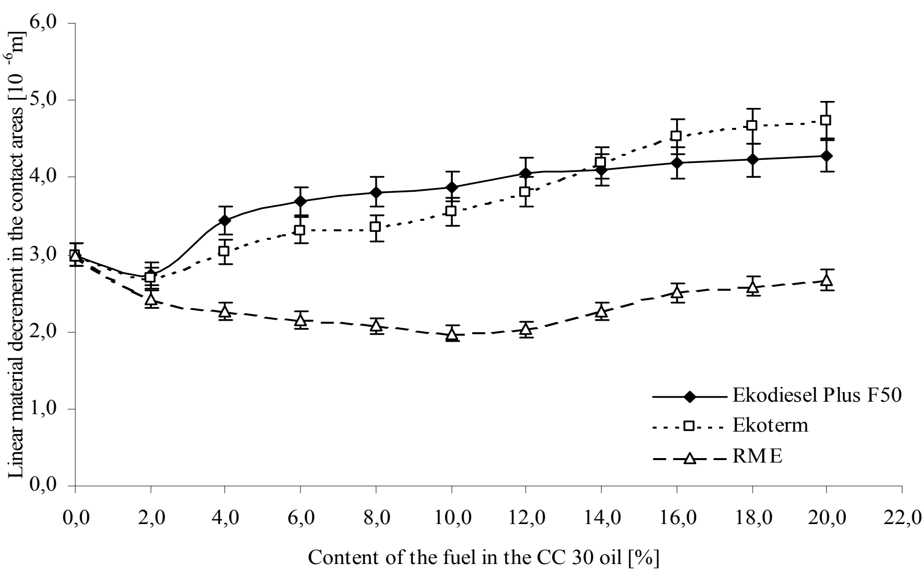

Fig. 2. Consolidated changes in the values of the wear of the samples made from steel type ŁH 15 depending on the content of the fuel in the CC 30 lubricant

Fig. 3 shows the changes in the roughness of the surface of the wear (according to parameter R_a) depending on the percentage content of the fuel in the CC 30 engine oil. In the tribological tests when lubricated with the base oil and its mixtures with diesel oil, heater oil or RME (except the mixture of the base oil and 20% RME) the smoothing of the contact surface by a single roughness class occurred – on average the reduction of parameter R_a by 50% was obtained. In the case of the mixture of CC 30 engine oil and the 20% addition of RME the R_a value dropped only by approximately 35%.

The lubrication of the analyzed node with the CC 30 engine oil with the addition of heater oil did not cause such an evident smoothing of the surface in the wear areas. As the content of the heater oil grew in the engine oil, the value of parameter R_a increased in such a way that at 14% addition the character of the roughness profile changes (Fig. 3, dotted line) did not significantly differ from the base profile of the samples after polishing (Fig. 3, bold continuous line).

Based on the course of the changes of the characteristics observed in the comparative tests (Fig. 2) an assumption was made as to the possibility of formation of metal-organic boundary sorptive layers in the contact area lubricated with engine oil with the addition of RME, that are initiated by the influence of dipolar RME particles contained in the lubricant. Physically and/or chemically sorped surface layers, resistant to pressure and of limited resistance to shearing, may reduce the material decrement under sliding friction (mechanical chemical form of wear) minimizing the risk of pathological friction wear i.e. micro cutting and grooving [Hebda, Wachal 1980; Bowden, Tabor 1980; Laber S., Laber A. 1997]. This leads to a stabilization of the roughness to a state of balance under given conditions of the sliding pair (Fig. 3) and prevents the development of the seizure even if the surfaces in contact are not permanently separated with a lubricant film [Wanke 2003].

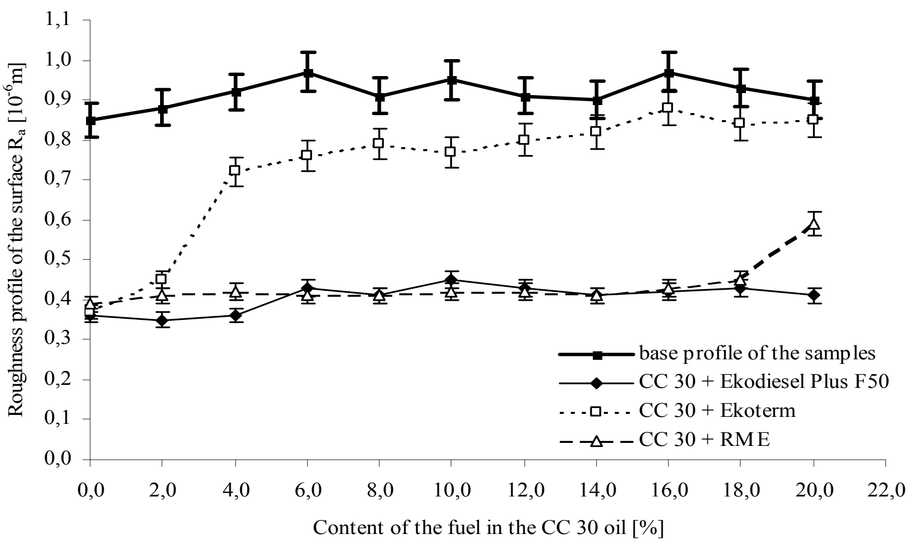

Fig. 3. Consolidated changes in the value of parameter R_a of the roughness profile of the samples made from the steel type ŁH 15 depending on the percentage content of the fuel in the CC 30 lubricant

In the case of lubrication with a mixture of engine oil and diesel oil or heater oil the influence of the described process on the tribological interactions in the sliding pair is reduced – probably due to the change in the rheological properties of the lubricant resulting from the changes in the viscosity accompanying the addition of the fuel in the lubricant. The smoothing of the surface in the friction areas, while there is no reduction of the sample wear, observed when lubricated with mixtures of CC 30 engine oil and diesel oil was most probably caused by the anti-seizure additives in Ekodiesel Plus F50 having a lower sulfur content. Under the conditions of boundary lubrication the effect of stabilization of the microgeometry of the surface was obtained while the wear processes could still be intensified [Wanke, Batko 2008].

The investigations are being continued to verify and detail the results and possibly eliminate incidental errors resulting from inaccuracy of the measurement methods. The authors focused on the explanation of the causes of the observed differences in the nature of the changes in the sample wear and the microgeometry of the surface in the friction contact area.

CONCLUSIONS

1. The oil bath type lubrication of the samples made from the steel type ŁH 15, under the conditions of sliding friction at concentrated steel to steel linear contact with a CC 30 engine oil mixture with RME (range 2÷20)% by volume causes a reduction of the wear as opposed to lubrication with the base oil in the whole test range under analysis. The most advantageous conditions were obtained for (10÷12)% by volume of the RME addition – which resulted in a linear reduction of the material decrement in the contact areas by approximately (32÷34)% as opposed to the lubrication with the base oil.
2. The lubrication, realized under analogical test conditions, with the mixture of CC 30 engine oil and diesel oil or heater oil results in a reduction of the sample wear by approximately 10% on average as opposed to the lubrication with the base oil only for 2% content of the additives of the fuels under analysis. In the case of all other volumetric proportions of the lubricating mixtures, a growing trend of the wear was obtained expressed in an increase of the linear decrement of the material in the friction contact surface by 45% on average (for CC 30 with a 20% addition of diesel oil) and approximately 55% (for CC 30 with a 20% addition of heater oil).
3. The application of RME or diesel oil in the CC 30 engine lubricant in the range of (2÷20)% by volume initiates a smoothing of the surface of the samples in the areas of wear traces by one class of roughness according to parameter R_a and results in a stabilization effect of the microgeometry of the surface to a state of balance under given conditions of the sliding pair. The lubrication of the analyzed friction node with mixtures of engine oil and heater oil does not influence the surface smoothing this much. Along an increase in the heater oil content, a growth of the value of parameter R_a occurs to such an extent that already at 14% addition the nature of the changes of the roughness profile on the wear traces does not significantly differ from the base profile of the samples after polishing.

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ANALIZA ZUŻYCIA SKOJARZEŃ ŚLIZGOWYCH SMAROWANYCH OLEJEM KLASY CC 30 Z DOMIESZKAMI PALIW STOSOWANYCH W SILNIKACH ZS

Streszczenie. W pracy omówiono wyniki porównawczych badań laboratoryjnych, opisujących zmiany wartości zużycia próbek wykonanych ze stali ŁH 15, współpracujących w skojarzeniu ślizgowym typu stal – stal, w warunkach smarowania zanurzeniowego olejem silnikowym klasy CC 30 z domieszkami paliw Ekodiesel Plus F50, Ekoterm oraz RME w zakresie (2÷20)% objętościowo.

Słowa kluczowe: tarcie ślizgowe, zużycie, smarowanie, paliwa do silników ZS.