EGTRIB Journal
JOURNAL OF THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 7, NO. 4, OCTOBER 2010, 15 - 27

ANTIWEAR PROPERTIES OF THE BLENDS OF MINERAL AND SYNTHETIC OILS

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ABSTRACT
Nowadays, there is an increasing trend to use synthetic oils to lubricate automotive engines working under severe conditions. To overcome the fact that synthetic oil is more expensive than mineral oil it is proposed to use blends of the two oils.

The present work aims to investigate the antiwear properties of mineral and synthetic oil blends. The tested oil blends with different concentrations were preheated to 100 $^{\circ}$C for 50, 100 and 150 hours. Testes were carried out to investigate the effect of preheating on the antiwear properties of steel lubricated by the blends. Cross pin wear tester was used in the experiments.

Based on the experiments, blending mineral oil by synthetic oil should be followed by a preheating process. The best wear resistance can be obtained by preheating the blends mineral and synthetic oil for 50 hour at 100 $^{\circ}$C. Addition of synthetic oil to mineral oil up to 70 % can significantly reduce wear. Abrasive wear was reduced through increasing the preheating time up to 50 hours. As the grit size increased wear increased. This behaviour was attributed to the increasing embedment of sand particles in the steel counterface.

KEYWORDS
Synthetic oil, mineral oil, antiwear, preheating.

INTRODUCTION
The reduction of wear and friction losses in an internal combustion engine is largely a function of improved lubrication. Therefore, advanced lubricants are now being formulated to reduce the wear and friction of the tribological component of the engine. The development of modern lubricants and their proper use are of great importance for the national economy, individual and environment. Lubricants, optimally adjusted to a given task, can save billions of dollars in the case of an industrialized nation, reduce wear, reduce maintenance requirements and the problem of air pollution [1].

The lubricant in an internal combustion engine serves several purposes, important among them are maintaining fuel economy, reducing wear and providing corrosion protection [2]. The interaction of the lubricant with the solid surface results in the formation of a tribofilm with physical and chemical properties that are distinct [3]. Most of the wear in an engine occurs during start up where a thin layer of lubricant coupled with a pre-existing transfer layer or tribofilm is the only protection against metal on metal contact. The effectiveness of boundary lubrication is dependent on many variables that include the anti-wear additives and hardness of the contact surfaces [4 –6].With the drive towards improved fuel economy, lower viscosity oils are being used, which increases the role played by additives in protecting tribological surfaces under boundary lubrication.

Wear under boundary lubrication is controlled by the nature and effectiveness of the tribofilms formed on the surface. The extent of wear under boundary lubrication at a fixed load is directly proportional to the applied load with a linear increase in the extent of wear as the applied load is increased, [7]. The time for final break down of the protective tribofilm is inversely dependent on the applied load with larger loads resulting in shorter lifetimes. In addition, the time to failure and the extent of wear is dependent on the amount of lubricant used and contact load.

Adhesive wear occurred in the oil lubrication in a form of a material transfer from the upper specimen to the lower specimen. The worn surface of the lower specimen had scuffing cavities after seizure took place. This was accompanied by a sudden jump in friction coefficient and oil temperature. Seizures and scuffing were thus occurred at small contact areas of the two sliding surfaces, where high contact temperatures were generated due to the concentrated frictional heat, [8]. The high temperature in the cavity region allowed the production of a reaction layer on the lower specimen substrate.

Improvement of the characteristics of power transformers could be achieved via the improvement of the insulating fluid characteristics. In that sense, it appears that the mineral oil / 20% synthetic ester oil mixture is a good compromise to get a liquid that performs better than mineral oil alone. Indeed, this mixture produces a small change in viscosity, a higher BDV and a better ageing stability than mineral oil alone, and a moderate increase in ECT effect. Thus, either the reliability of existing power transformers could be improved, or the size (and the price) of new power transformers could be decreased by using smaller insulating gaps.

Lubricants consist of base oils and additives. Base oil are hydrocarbons and they tend to oxidize, thermally decompose, and polymerize, [9]. Studies revealed that the hydrocarbons react with oxygen and form polar species such as carboxylic acids which adsorb into the metal surface and react with the metal forming metal complexes [10]. These metal complexes are soluble in oil. Friction and wear were further studied using a series of additives, vegetable oils and esters, [11, 12]. The effect of the polar molecules of the base fluids on their ability to lubricate under boundary conditions was studied, [13]. The effect of polar groups, such as carbonyls, alcohols and olefins, branching and effective carbon chain length are included as factors that have the potential to effect wear, [14 – 16]. Although the various polar groups did affect the wear rate, they did not control friction. It was found that the predominant factor affecting friction was the effective chain length. Besides, low temperature properties improve as the number of double bonds or branching increase.

During sliding, chemical reactions are produced as a result of the frictional heating. These reactions include oxidation of the surface, lubricant oxidation and degradation, surface catalysis, polymerization, and the formation of organometallic chemistry, [17]. These reactions produce inorganic products of various molecular weights up to 100,000 for hydrocarbon lubricants. Precipitation of high molecular weight products from solution forms films of friction polymers, [18 – 20]. It was suggested that the chemical compositions of the films are mainly micrometer and submicrometer sized particles of iron and iron oxides as well as high molecular weight organometallic compounds.

Methyl esters of fatty acids derived from rape-seed oil and used as fuel oil additives can favourably modify its lubricating properties. This is due to the relatively high surface activity of the esters. The experiments have confirmed that surface tension of solutions of the esters in fuel oil increases with an increase in their concentration and for 100% solutions it reaches values that are 1.5-fold lower than those for fuel oil [21]. A relatively stable lubricant film forms as a result of adsorption interactions. It has been found that a percentage share of the lubricant film in covering the surface under friction conditions increases with an increase in concentration. As a result, motion resistances and roughness decrease as a function of concentration. The variations in the corrected wear scar diameter (WS 1.4) and wear profile as a function of concentration are more complex. A pronounced minimum can be observed in the concentration range of 10–20%. The minimum value is about twice lower than the one for fuel oil. An increase in the corrected wear scar diameter at higher concentrations may be connected with a decrease in surface roughness, [22].

The aim of the present work is to investigate the effect of antiwear properties of the blends of mineral and synthetic oils examined by the cross pin wear tester.

EXPERIMENTAL WORK

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists, mainly, of a rotating pin and stationary one of 14 mm diameter and 120 mm long. The materials of the pins are alloy steel of 746 MPa ultimate tensile strength and 1540 MPa Vickers hardness.

Two sets of experiments were carried out. In the first set of experiments, adhesion test to investigate the tribological behaviour of smooth surfaces when lubricated by clean oil. In the second set of experiments, abrasion test was used to investigate the effect of contamination as well as rough surfaces on wear. Abrasion test was used by covering the rotating pin by sand papers of 220, 320 and 400 grits. Mineral oil used in the experiments was SAE 40 while synthetic oil was SAE 5W-50.

The tested oil samples were prepared by blending mineral oil by different content, 0, 10, 30, 50, 70, 90 and 100 % of synthetic oil. The blends were preheated to 100 °C for 50, 100 and 150 hours. Wear tests were carried out at 650 r.p.m sliding speed (0.48 m/s) and 4, 6, 8, and 10 N normal loads for 2 minutes. Prior to and after each test, the tested pins were cleaned with solvent and dried in air. At the beginning of the test the contact area was lubricated by 1.0 cm^3 of oil then every 30 seconds relubrication was applied. Wear scar diameter of the stationary pin, as a measure of wear, was determined using optical microscope at the end of the experiments.

RESULTS AND DISCUSSION

The results of the experiments are shown in Figs. 2 – 17. The results of adhesion wear tests are illustrated in Figs. 2 – 9.

The tribological behaviour of mineral and synthetic oil blends is shown in Fig. 2. The wear scar diameter increased as the content of synthetic oil increased. Generally, mineral oil showed lower wear values than that observed from synthetic oil. It seams that the antiwear properties of synthetic oil depended on the decomposition products. These products decompose after certain running distance at high temperature inside the engine.

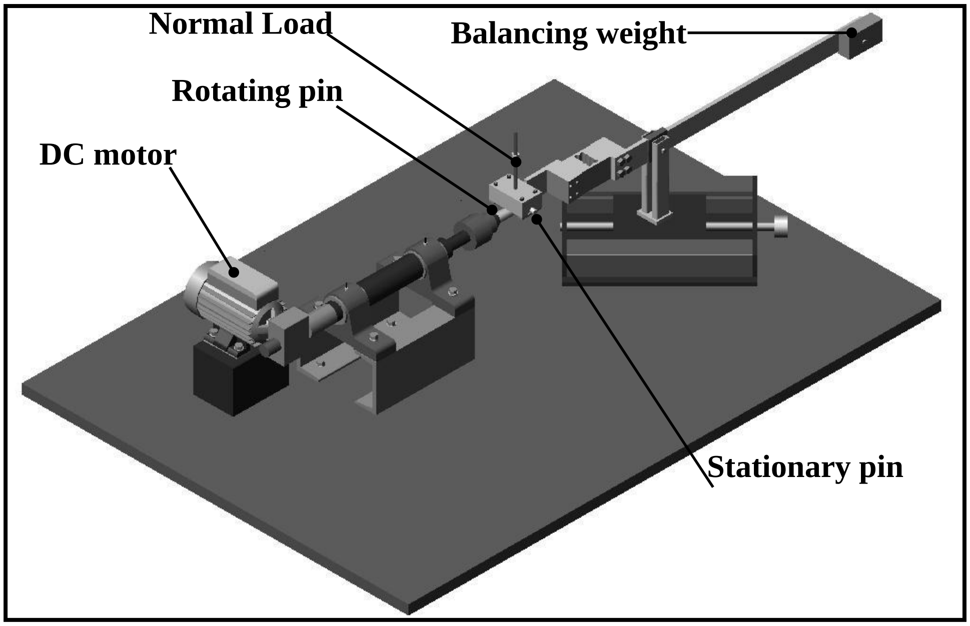

Fig. 1 Arrangement of the wear tester.

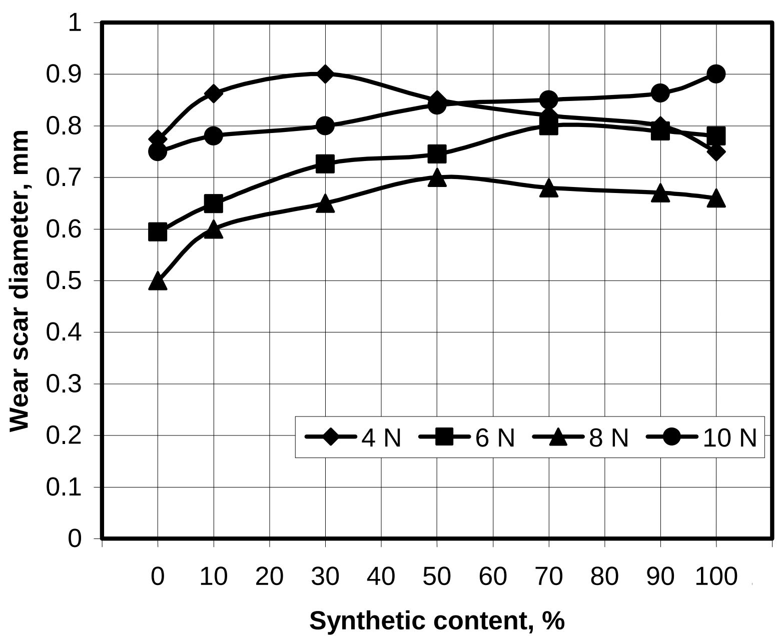

Fig. 2 Wear scar diameter versus synthetic oil content.

To investigate the effect of preheating on the antiwear properties of the blends, preheating process was carried out. After preheating, the effect of load on wear scar diameter versus synthetic oil content is shown in Fig. 3. It can be noticed that the wear scar diameter increased with increasing applied load. This behaviour is related to the increase the contact area. As the synthetic oil content increased wear slightly decreased. As for the preheated oils to 100 °C for

50 hours, the synthetic oil showed the lowest values of wear. This behaviour is attributed to the best tribological behaviour displayed by decomposition products of synthetic oil.

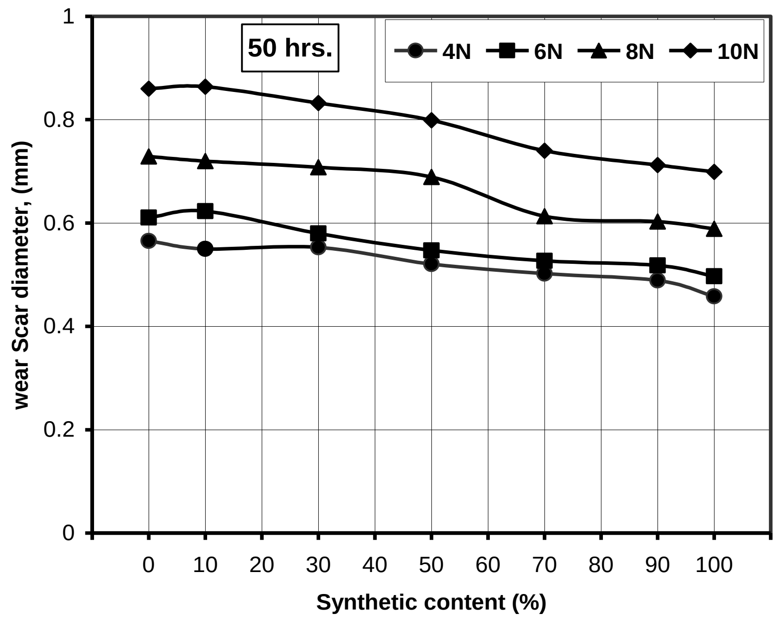

Fig. 3 Wear scar diameter versus synthetic oil content.

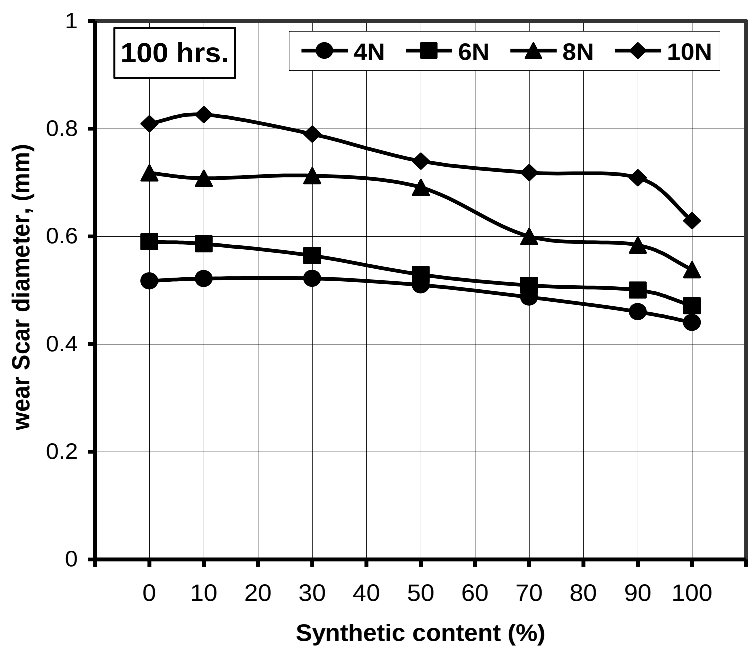

Fig. 4 Wear scar diameter versus synthetic oil content.

The effect of load on wear scar diameter versus synthetic oil content preheated to 100 ˚C for 100 hours is shown in Fig. 4. Generally, the wear scar diameter increased with increasing applied load. Values of wear displayed by blends preheated up to 100 hours were lower than that displayed by blends heated up to 50 hours. This behaviour is attributed to the increase of the decomposition products of synthetic oil. The same behaviour was noticed in Fig. 5 when heated the blends up to 150 hours.

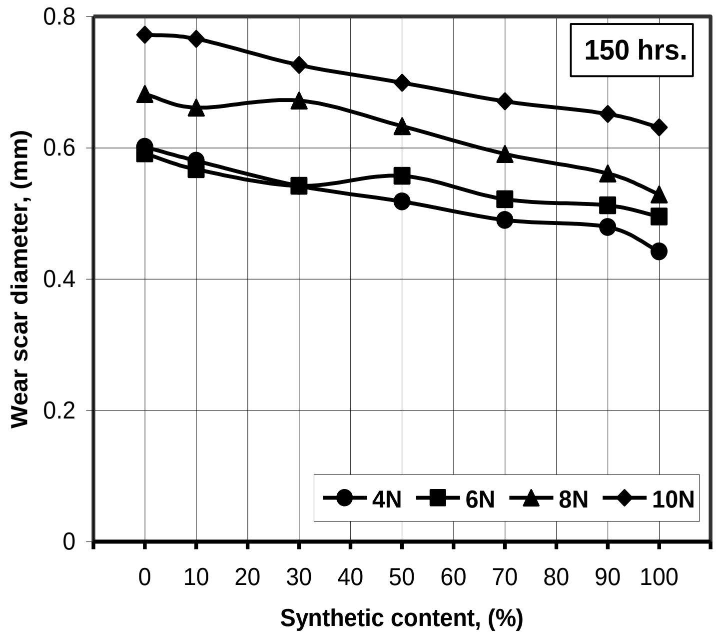

Fig. 5 Wear scar diameter versus synthetic oil content.

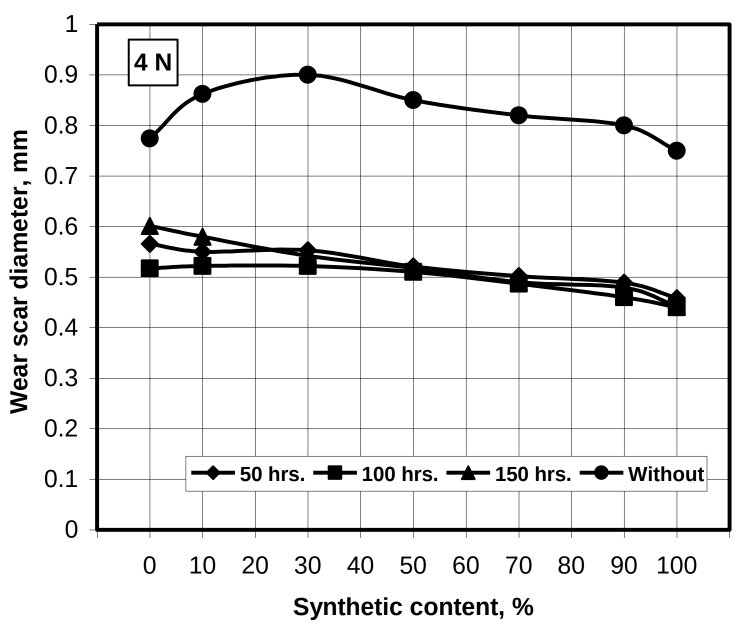

Fig. 6 Wear scar diameter versus synthetic oil content.

Based on the results of wear shown in Fig. 6, it can be seen that there is no significant influence of increasing preheating time on wear of the tested specimens. This observation confirms that the best preheating time was 50 hours. Preheating oil blends decreased the wear values up to 30 %. Generally, the wear decreased with increasing synthetic oil content. This behaviour may be due to the fact that synthetic oil covered the surface of contact area forming an oil film separating the two contact surfaces. The values of wear increased at applied load 6 N, Fig 7. As the load increased the contact area increased.

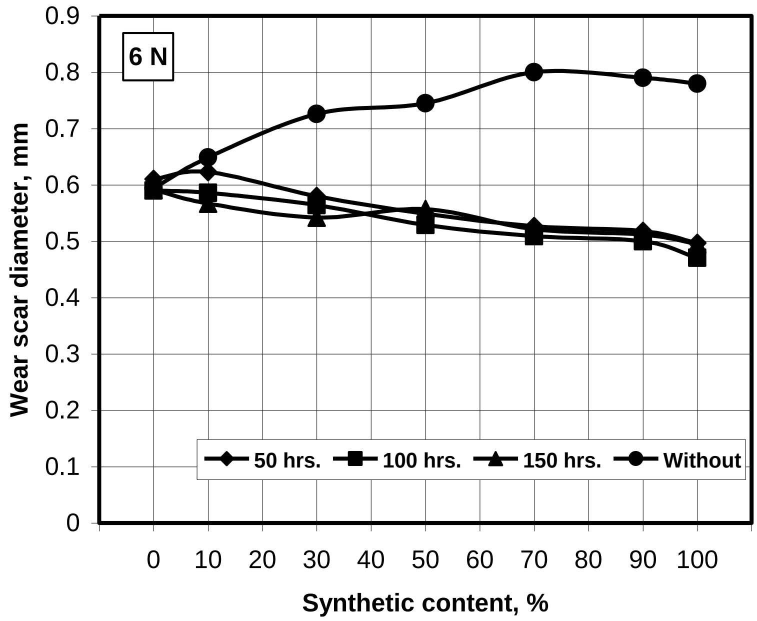

Fig. 7 Wear scar diameter versus synthetic oil content.

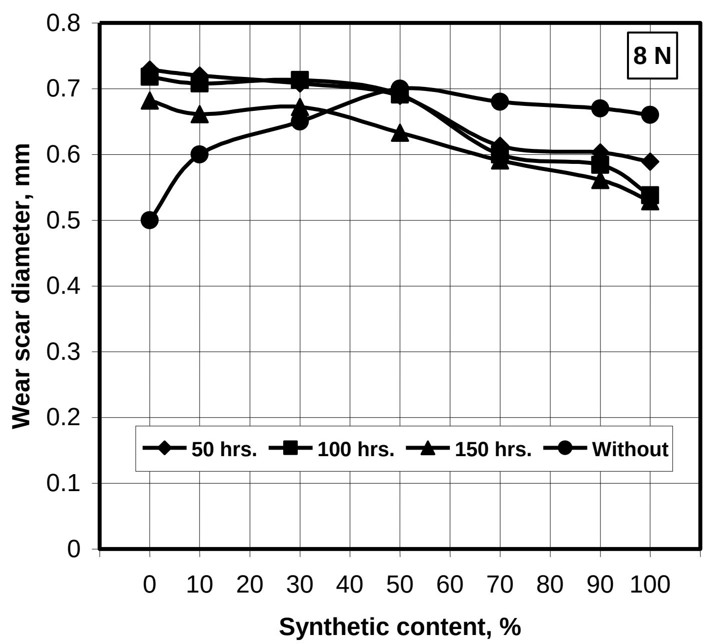

Fig. 8 Wear scar diameter versus synthetic oil content.

Wear caused by 8 N load is shown in Fig. 8. As the load increased the values of wear increased, this behaviour can be explained on the basis that increasing applied load break down the oil film that separating the contact surfaces. Increasing preheating time up to 50 hours was insignificant. Further increase of wear values were observed by increasing applied load up to 10 N, Fig. 9.

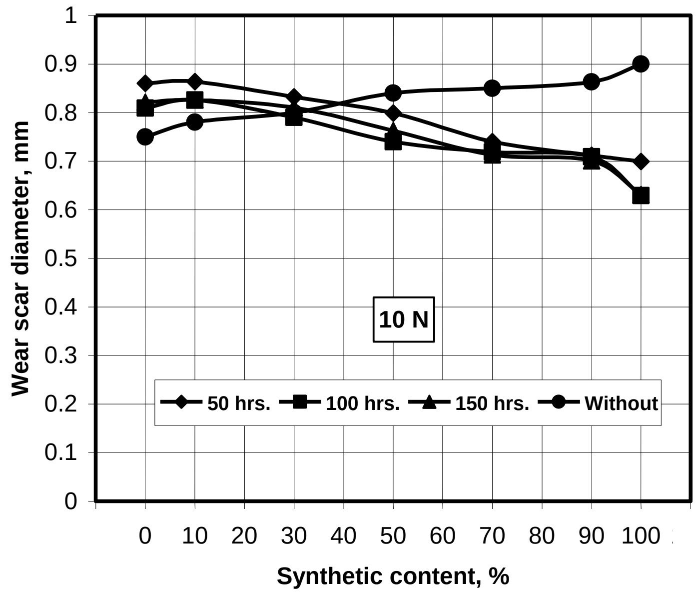

Fig. 9 Wear scar diameter versus synthetic oil content.

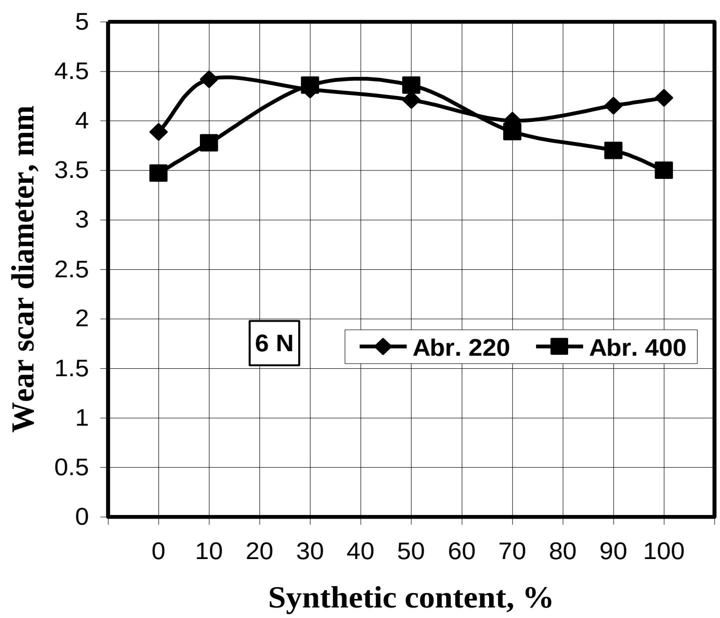

Fig. 10 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

Abrasion wear are illustrated in Figs. 10 – 17**.** Wear of the test specimens sliding against rough surfaces is shown in Figs. 10, 11, 12 and 13. Generally, it can be noticed that the prehating oil blends decreased wear with increasing synthetic oil content. This behaviour can be attributed to the preheating process leads to the formation of the decomposition products in synthetic oil. The best preheating time was 50 hours. Increasing grit size increased the wear values. This behaviour can be discussed on the basis that the sand particles break the oil film covering on the contact surface and embedding in the steel surface and consequently abrading the steel surfaces. As the sand particles abrade the steel surface, there are two methods for reducing wear. First method is to increase the hardness of the surface by chemisorbed layer caused by the action of the additives in oil and steel surface. The second method is to provide the surfaces by physisorbed layers on the contact surfaces to reduced friction between sand particles and steel surface.

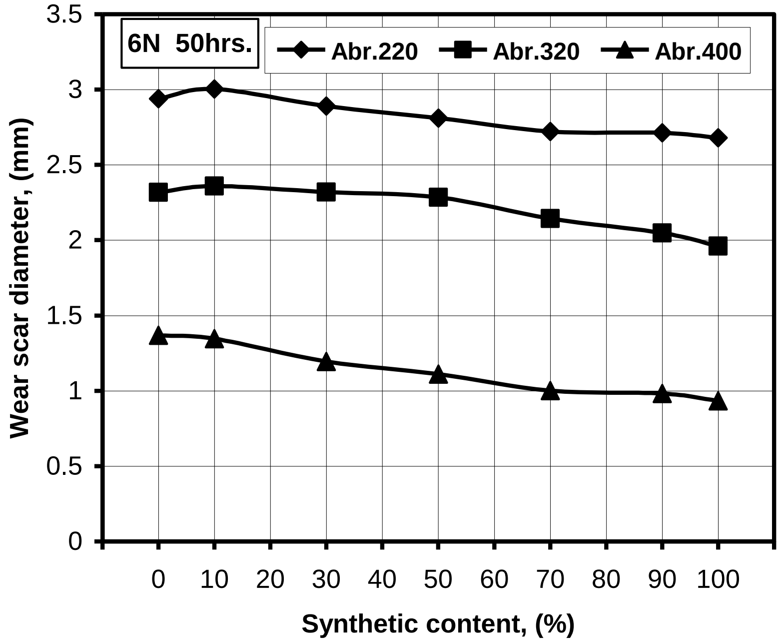

Fig. 11 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

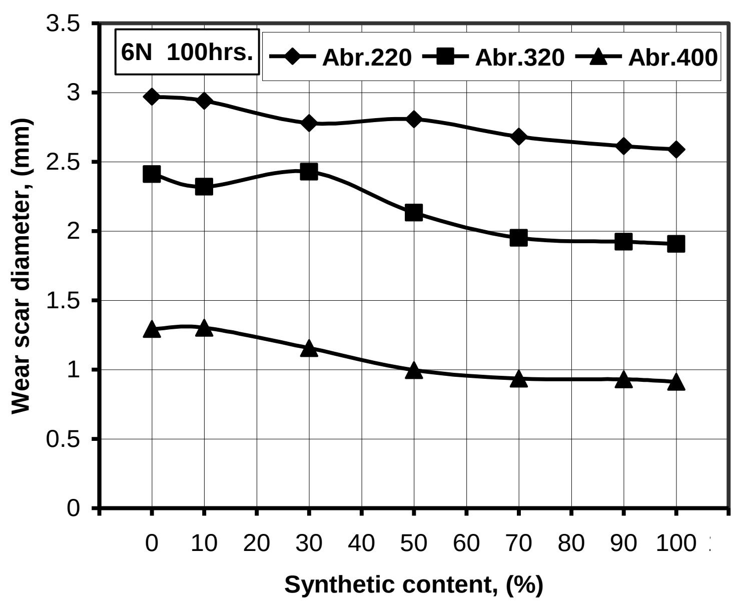

Fig. 12 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

Effect of increasing applied load on wear when sliding against rough surface is shown in Figs. 14, 15, 16 and 17. Generally, it can be noticed that the wear values increased compared to 6 N applied load. As the applied load increased the contact area between contact surfaces increased. It can be seen that the same trends observed for 6 N applied load.

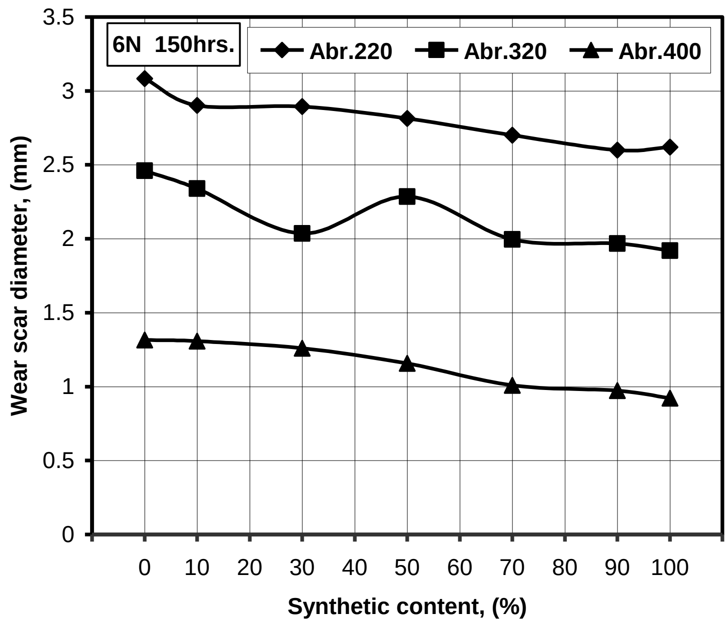

Fig. 13 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

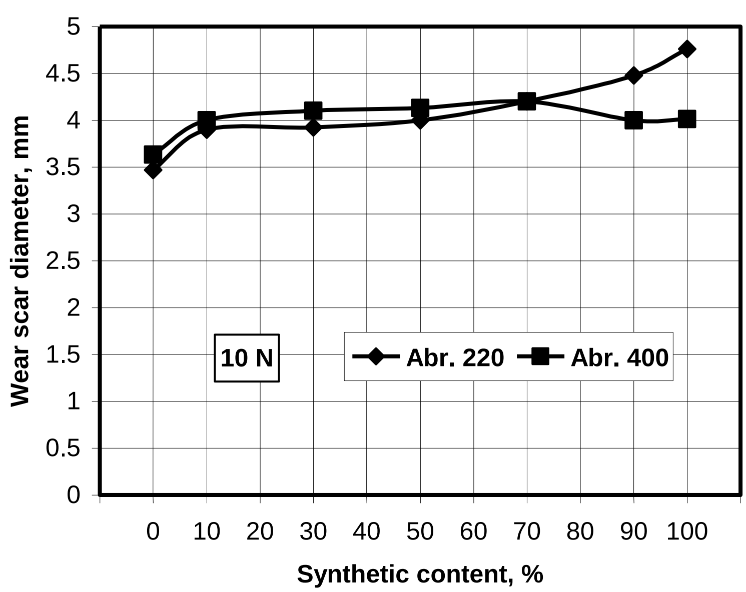

Fig. 14 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

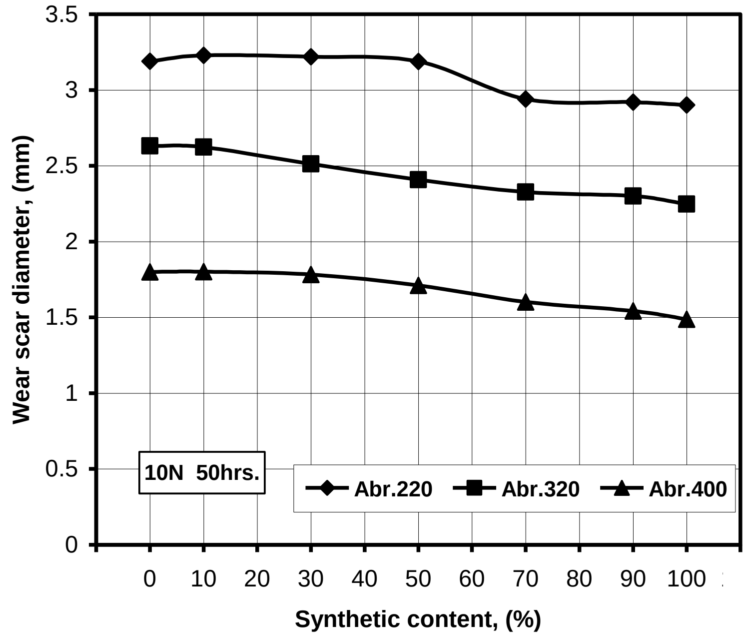

Fig. 15 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

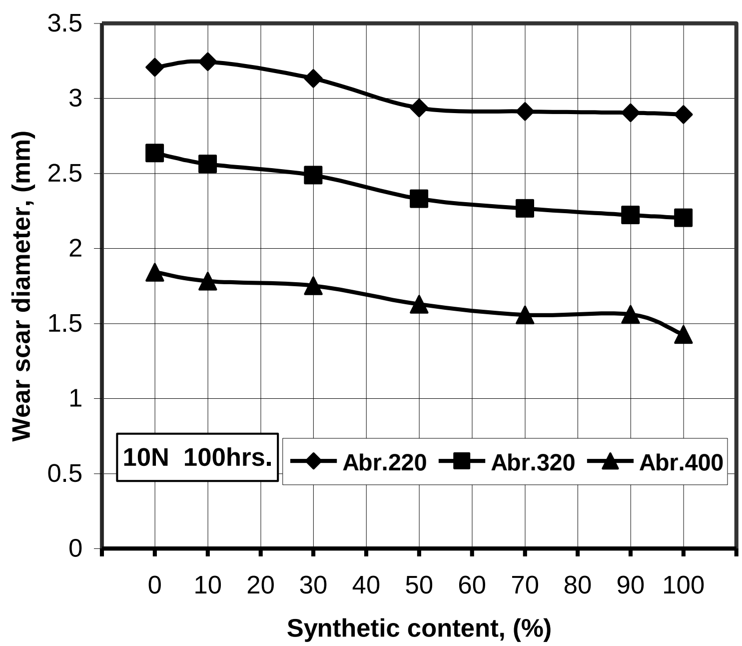

Fig. 16 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

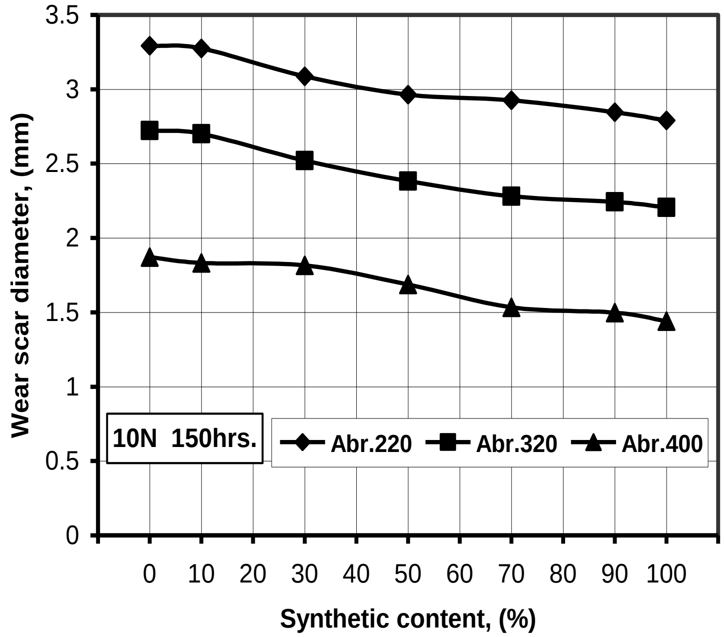

Fig. 17 Wear scar diameter versus synthetic oil content when sliding against abrasion surface.

CONCLUSIONS

1. Blending mineral oil by synthetic oil should be followed by a preheating process.
2. The best wear resistance can be obtained by preheating the synthetic oil blends for 50 hour at 100 ˚C.
3. Addition of synthetic oil to mineral oil up to 70 % wear decreased.
4. In abrasion test increasing the preheating time up to 50 hours for synthetic oil blend was insignificantly on the wear.
5. As the sand particles increased wear increased. This behaviour is attributed to increase of the embedment of sand particles in counterface.

REFERANCES

1. Klamman D. Lubricants and related products. 1st ed. Verlag Chemie, (1983).
2. Khorramian B. A., Iyer G. R., S. Kodali, P. Natarajan, R. Tupil, "Review of antiwear additives for crankcase oils", Wear 169 (1), pp. 87–95, (1993).
3. Hardy W. B., "Collected Scientific Papers of Sir William Bate Hardy", Cambridge University Press, Cambridge, England, (1936).
4. So H., Lin R.C., "The combined effects of ZDDP, surface texture and hardness on the running-in of ferrous metals", Tribology International 32 (5), pp 243–253, (1999).
5. Sheasby J. S., Caughlin T. A., Mackwood W. A., "The effect of steel hardness on the performance of antiwear additives", Wear 201 (1–2), pp. 209–216, (1996).
6. Bell J. C., Richards M. N., "Some effects of hardness and microstructure on the lubricated wear of steels", in: Proceedings of 14th Leeds/Lyon Symposium on Tribology, pp. 343–353, (1987).
7. Gabi Nehme, Ramoun Mourhatch, Pranesh B. Aswath, "Effect of contact load and lubricant volume on the properties of tribofilms formed under boundary lubrication in a fully formulated oil under extreme load conditions", Wear 268, pp. 1129-1147, (2010).

8. Hsiao Yeh Chu, Wen Chen Hsu, Jen Fin Lin," Scuffing mechanism during oil-lubricated block-on-ring test with diamond nanoparticles as oil additive", Wear 268, pp.1423 –1433, (2010).
9. Castro W., Weller D., Cheenkachorn K., Perez J., "The Effect of Chemical Structure of Base Fluids on Antiwear Effectiveness of Additives" , Tribology International, 38, PP. 321 – 326, (2005).
10. Hsu S., Klaus E., Cheng H., "A Mechano-Chemical Descriptive Model for Wear Under Mixed Lubrication Condition", Wear, 128, pp. 307 – 315, (1988).
11. Weller, Jr D., "Study of the Effect of Chemical Structure of Esters and Vegetable Oils on Friction and Wear'' , Ph. D. Thesis. The Pennsylvania State University, University Park, PA 16802; (2000).
12. Cheenkachorn K., "A Study of Structure Effects on Oxidative Stability of Soybean Oils", Ph. D. Thesis. The Pennsylvania State University, University Park, PA 16802; (2003).
13. Ali W. Y., Khattab A. A. and Heshem A., "Effect of Externally Applied Voltage on Lubricant Additives Behaviour", Proceedings of the VI. Budapest Tribology Conference. Budapest Technical University, June 6 – 7, pp. 188 – 198, (1996).
14. Perez J., Weller Jr D., "A Study of the Effect of Chemical Structure on the Friction and Wear of Several Environmentally Friendly Fluids', Proceedings of the international tribology conference, Nagasaki, Japan 2000, pp. 21 – 26, (2000).
15. Weller Jr D., Perez J., "A Study of the Effect of Chemical Structure on the Friction and Wear, Part 1: Synthetic Ester Base Fluids'', Lubricant Eng 2000, 56 (11), pp. 39 – 44, (2000).
16. Weller Jr D., Perez J., "A Study of the Effect of Chemical Structure on the Friction and Wear, Part 2: Vegetable Oils and Esters'', Lubricant Eng 2001, 57 (5), pp. 20 – 26, (2001).
17. Nakayama K., Hashimoto H., "Triboemission From Various Materials in Atmosphere", Wear, 147, pp. 335 – 342, (1991).
18. Gates R., Jewett J., Hsu S., "A Study on the Nature of Boundary Lubricating Film: Analytical Methods Development", Tribol Trans; 32, pp. 423 – 434, (1989).
19. Lindsay N., Carter R., Schmitz P., Hack L., Chase R., de Vries J., Willerment P., "Characterization of Films Formed at a Lubricated Cam/Tappet Contact", Spectrochim Acta, 49A, p. 2057, (1993).
20. Briscoe B., Thomas P., Williams D., "Microscopic Origins of the Interface Friction of Organic Films: the Potential of Vibrational Spectroscopy", Wear, 153, pp. 263 – 377, (1992).
21. Sulek M. W., Kulczycki A., A. Malysa, "Lubricative Properties of Biodiesel Based on Fatty Acid Methyl Esters and Fuel Oil Conference Papers: Tasks of Polish Fuel Sector in Biodiesel Promotion", Institute of Fuels and Renewable Energy,Warsaw, (2006).
22. Sulek M. W., Kulczycki A., Malysa A., "Assessment of lubricity of compositions of fuel oil with biocomponents derived from rape-seed", Wear 268, pp. 104–108, (2010).