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The Wear of Aluminum in the Presence of Polytron Additive in the Helix Lubricant; A Quantitative Analysis

Syed Mohammad Hasan Ahmer, Lal Said Jan

Abstract — *We have investigated the effect of polytron as an antiwear additive in the base oil Helix. The objective of this study was to examine surface analysis and wear rate of the metal (aluminum). Wear studies were performed on the Pin-on-Disk (POD) tribometer with a fixed load of* $\mathbf{196.2\ N}$ *under dry air conditions. The wear of the metal surface with the base lubricant was found to be approximately* $\mathbf{75\ micron}$*. Upon the addition of polytron additive to the base oil, the surface scar of the metal showed a considerable decrease in its wear, which can be related to the chemical and/or physical changes and the formation of a hard surface film introduced by polytron in the system. In fact, the addition of* $\mathbf{10\%}$ *by volume of polytron to the base oil reduced the value of wear to* $\mathbf{25\ micron}$ *which indicates a pronounced decrement of one-third of the initial value of wear. The mass wear rate of the metal without the additive was estimated at* $\mathbf{3.3 \times 10^{-3} mg/min}$ *which, in the presence of polytron additive, decreased by an order of magnitude, i.e.* $\mathbf{8.33 \times 10^{-4} mg/min}$*. Quantitative studies show a direct correlation between the wear coefficient and wear rate.*

Key Words — Wear-coefficient, helix, friction, polytron, tribology.

I. Introduction

When contact surfaces in an engine and/or any machinery are observed under high magnification of a microscope, one can see that they are actually full of mountains and valleys. In dynamic conditions, these so-called mountains can even penetrate an oil-film between the contacting surfaces, and collide with each other. These collisions at the microscopic level translate into friction at the macroscopic level. Some of these collisions result in metal particles breaking away from the colliding mountains. The broken metal particles at the microscopic level are what we see as wear process at the macroscopic level [1]. Lubricants are those materials which are used to reduce this friction and wear. In most applications such as automobile engines and complex machinery parts the base lubricant is not sufficient to give a long life to the parts. The usual solution is in the addition of a relatively small amount of additive compounds that provide significant improvement of base oil properties with regard to either oxidative degradation or tribological and other performance characteristics [2 - 4]. Most of the additives comprise polar functional groups and belong to various classes of organic or organometallic compounds. The tribo-active additives generally contain tribologically active elements or combinations thereof, e.g, phosphorous (P), sulphur (S), chlorine (Cl), zinc (Zn), nitrogen (N), and tungsten (W) that are capable of forming protective tribological inorganic or comparable layers on frictional surfaces on account of reactions with the constituent material (iron or its alloys in most cases). The first step of their action mechanism is usually physical and/or chemical adsorption on entire metal surface and chemical modification process takes place only in the friction contact zone when wear process starts. The monomeric antiwear (AW) and extreme pressure (EP) additives usually comprise of these one to six tribologically active elements in their molecules and it is often necessary to add up to 5 wt% of such additives to prevent a serious metal surface depletion. In point of fact, lubricants based on synthetic hydrocarbon-type mixtures do not meet all the requirements provided by original equipment manufacturer for the lubricating materials used in modern engines, gear or any other pairing machinery parts. The usual solution is in addition of relatively small amounts of certain additive compounds that provide significant improvement of base oil properties with regard to either oxidative degradation or tribological and other performance characteristics [5 -14]. In many applications the wear reduction mechanism and a quantitative analysis of these additives are not well known and a thorough exploration is inevitable. In the list of additives, one such uncommon antiwear additive is polytron that necessitates a scientific effort in order to understand the interaction mechanism of polytron with metal substrates, and the consequent smoothening and lubrication of the interacting surfaces. Polytron is an oily fluid mixture of petroleum based chemicals mixed with oxidation inhibitor and detergent chemicals, which at ambient pressure and temperature is a stable grease in stark contrast with the conventional lubricants that are based upon maintaining high strength and thickness of oil film and/or on introducing an Extreme Pressure (EP) protective deposit between moving mating surfaces to resist failure that may result in scoring, seizure or accelerated wear. Polytron additives are 100% petroleum based, contain no solid particles, and, above all, are compatible with all the lubricants on the market. Since polytron metal treatment concentrate (MTC) is polarized, it is attracted to metal surfaces and through metallurgical process forms a durable polished-like microscopic layer on metal that vividly resists wear, extreme pressure and excessive temperature. When polytron is applied, under the conditions of heat and pressure generated by friction of the moving parts, some of its elements impregnate

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metallurgicallyl the crystal structure of the metal itself at the coupling friction generating surfaces. As a result of the metallurgical process, a very thin layer of the original metal is converted into a new significantly harder metal, which on that account affords much longer wear-life for the metal surface. This newly formed layer of metal protects the original softer metal beneath it from any wear. Since the protective layer is very thin, it is as flexible as any ordinary thin sheet of metal. Although during collisions the protective layer does not allow metal particles to break away, its flexibility allows the metal underneath to be pushed horizontally by the horizontal force generated by collisions. Thus the metal on the fictional mountains in the metallic surfaces is pushed into the self-proclaimed valleys therby flattening out the friction surface. The consequence of this intertwined course is a smooth polished-like surface that has a much lower friction coefficient [15]. In this investigation, we have undertaken experimental studies on the polytron additive in a base lubricant to assess the formation of a reaction film on the rubbing surfaces of the metals and the ensuing antiwear protection capability of polytron. We performed fixed loading studies of wear versus time in order to establish the wear effectiveness of polytron and to define the operating conditions for active surface films. In this article, we will present our preliminary observations on how to curtail the wear and friction of a metal-metal contact in automotive parts like engine and gear and other machinery.

II. MATERIAL AND METHOD

We used graduated cylinders in order to ensure precise addition of base lubricant Helix and the additive polytron. The glassware and containers used in the preparation of these solutions were first cleaned with hot water and soap, and then rinsed with hot tap water and rinsed six times with distilled water. Finally, it was rinsed three times with acetone (*and/or ethanol*) and dried in an oven for 2 hrs at 110℃. The base oil Shell Helix (*Ultra 5W-40*) was supplied by the Shell Oil company, located in B. B. Bangi, whereas Polytron MTC was provided by Malaysian Association of Productivity (*MAP*), P.J., Selangor D. E. , Malaysia and were used as supplied. The data sheet for polytron is given in Table 1. It consists of 80 percent para polytron and 20 percent meta polytron. The base oil and additive solutions were prepared at room temperature. The solutions were then stored in brown bottles to eliminate possible light-induced degeneration. To run the wear tests, we used Pin-on-Disc (*POD*) Tester TR–20LE, Ducom Instr. Pvt. Ltd., Bangalore, India. We chose soft aluminum (*Al -1050*) metal for the pin whereas stainless steel (*SUS304*) was used as the disc material for the tribotester. The pure aluminum pin (*less than* 0.1% *impurities*) was given a final polish with $10\mu m$ alumina. The pins were then annealed in a vacuum furnace above the recrystallization temperature and cooled slowly in order to give a uniform hardness for all of the pins. This procedure gives reproducible wear measurements to $\pm 15\%$ [2]. The disc was lap ground and given a $600\mu m$ SiC final polish. This material combination was selected to guarantee wear on the much softer pin and not on the hard disk and to have a simpler chemical system. The data was obtained for separate test runs with the base oil Helix and then with Polytron (*10%*) as an additive.

TABLE 1
SHOWS THE DATA SHEET OF POLYTRON ADDITIVE

Physical and/or chemical property	Observed Value
Form	Liquid
Color	Yellowish clear
Smell	Odorless
Specific gravity	$\frac{60}{60} \approx 1.00$
Boiling point range	> 300 ℃
Flash point	> 200 ℃
Viscosity @ 100°F	SUS 391
Viscosity @ 210°F	SUS 61
Water solubility ($T = 20$ ℃)	Low
Evaporation Point	Higher than Ether

A. Test apparatus

The wear studies were performed with a Pin-on-Disk tribometer. The friction–and–wear apparatus was enclosed in a plexi-glass box which could be purged with dry air or nitrogen. The angular speed of the disc was determined by reducing the speed until the friction coefficient rose and saturated at the lowest load, thus guaranteeing operation in the boundary lubrication region.

B. Procedure

The wear experiment was then performed by sliding an annealed pure aluminum pin with a hemispheric tip of diameter 10.0 mm on the hardened steel disc. Pin load fixed at 20 kg was applied by a pulley system. For each run of the experiment and for each of the two solutions, an unworn position of the pin and a different face on the disc were used. For the Pin-on-Disc experiment, we took 2000 ml of the base oil (Helix) in a graduated cylinder. We used aluminum pin having a mass of 6.448 g, mean length of 32 mm and a diameter of 10 mm. The mean diameter of the disk was 80 mm. The sliding speed was calculated as 2.09 m/s which gives a sliding distance of 30164.2 m. The speed of the disc was kept at 500 rpm and the time of the test was fixed at 14400 seconds. In the first phase the base oil (Helix) was taken as 2000 ml (100 %). In the second case, the amount of Base oil (Helix) was 1800 ml (90 %) and the additive (polytron) was taken as 200 ml (10 %). The lubricant was applied to the disk surface at a flow rate of approximately 0.5 ml/min, consequently constantly supplying fresh lubricant. The disk was completely covered with lubricant before initiating the test. Wear volume was calculated from the pin wear scar diameters. Typical wear versus time plots for 20.0kg fixed load are shown in Figure 1. A polynomial fit was applied to the curve to see the trend of the data points and to determine mass wear rate (mg/min). This procedure was repeated for each solution and each condition in an independent test. Frictional force was measured by a piezoelectric transducer and was recorded as a function of time.

III. RESULTS AND DISCUSSION

In the first instance, the wear and wear rate of aluminum pin were obtained both in the presence of base lubricant and the additive. Measurements were performed on prior lubrication, i.e. the surfaces were exposed to the lubricant first and then the extent of wear, friction and/or scar depth were evaluated. A comparison plot of base lubricant and additive is shown in Figure 1 and Figure 2.

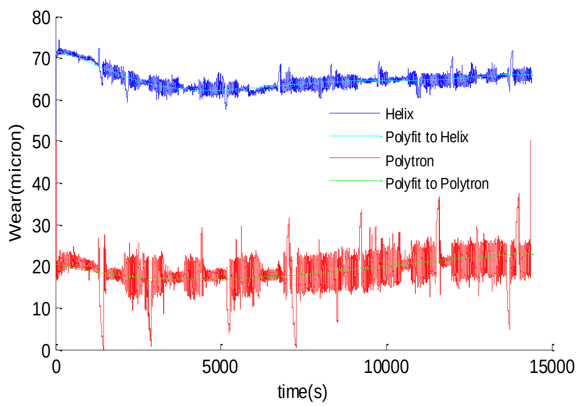

Fig. 1. A comparative plot of the wear versus time for the base oil Helix and the additive (Polytron). The time span for both the experiments was fixed at 240 minutes

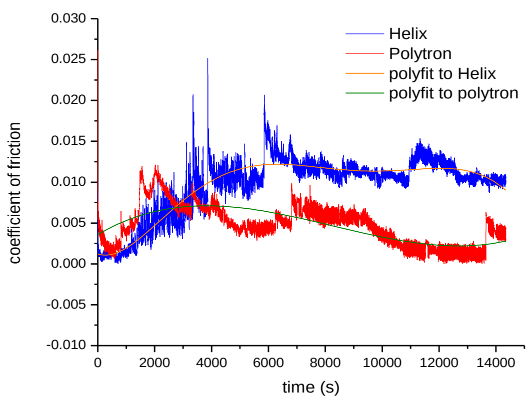

Fig. 2. A comparative plot of the coefficient of friction ver- sus time for the base oil Helix and the additive (Polytron). The time span for both the experiments was fixed at 240 minutes.

In Figure 1, we have plotted wear against time whereas Figure 2 elucidates graphically the progress of friction coefficient with time at room temperature (300K). It can be seen from Figure 1 that the wear for the base lubricant Helix is around 70 micron whereas the wear for the composite (i.e Helix plus Polytron) is 20 micron. It is a clear evidence that the polytron is reducing the wear of the pin significantly which is, in fact, more than 3 times. This claim is substantiated by an additional plot of the friction coefficient versus time. The plot is given in Figure 2. It is seen that Figure 1 and 2 go in consonance with each other. The contrast plot of Helix and the additive clearly shows the upshot of the polytron in the system. It can be discerned from this figure that polytron reduces the value of the friction coefficient more than 3 times as has been listed in Table 2. This value is markedly lower than the value reported in the literature for other additives. For example, the well-known additive ZDDP gives a friction coefficient value of 0.2 as has been reported by Suarez et al. [16]. It implies that polytron is protecting the surfaces, probably by forming a hardly adsorbed layer on the surfaces. It is expected that polytron will adsorb on the polar steel surfaces due to its own polar behavior. It is always desirable to have as low friction and wear of the parts in machinery as possible to help minimize the damage of the coupling surfaces. As we noticed, it can be achieved very conveniently by the use of polytron that is able to protect the surfaces against wear and it is this protective layer that finally breaks down the friction in the contacting surfaces.

TABLE 2
SHOWS THE TRIBOLOGICAL PARAMETERS OFALUMINUM PIN USED IN THE EXPERIMENT

Parameters	Helix (100%)	Helix (90%) + Polytron (10%)
Mass-wear rate	$\mathbf{3.33 \times 10^{-3} mg/min}$	$\mathbf{8.33 \times 10^{-4} mg/min}$
Volume-wear rate	$\mathbf{1.25 \times 10^{-3} mm^3/min}$	$\mathbf{4.17 \times 10^{-4} mm^3/min}$
Coefficient of friction	$\mathbf{0.012}$	$\mathbf{0.004}$
Wear coefficient ($\boldsymbol{k}$)	$\mathbf{1.27 \times 10^{-10} m^2/N}$	$\mathbf{4.22 \times 10^{-11} m^2/N}$

To arrive at a clear perception of the role of polytron additive in the Helix base lubricant, we proceeded further and evaluated three key factors that give valuable informations about the investigated system. They are termed as the mass wear rate, volume wear rate and wear coefficient as defined by (1), (2) and (3) respectively.

$$Mass\ wear\ rate = \frac{m(mg)}{t(min)} \tag{1}$$

In expression (1), $m\ (mg)$ stands for the mass of the pin being worn out and $t\ (min)$ speaks of the time span in the experimental observation.

$$Volume\ wear\ rate(volume) = \frac{V(mm^3)}{t(min)} \tag{2}$$

In expression (2), refers to the worn out volume of the pin and represents the time span in the experimental observation.

$$wear\ coefficient(k) = \frac{V \times H}{N \times S} \tag{3}$$

In expression (3), stands for the wear volume, for hardness of the sliding pin, for the normal load and for the sliding distance. The quantitative values of these parameters are given in Table 2. It can be easily concluded from these values that polytron diminishes the rate of both mass and volume of the pin by an order of magnitude. This suggests a strong interaction between Helix and steel surfaces in the company of polytron which points to a prominent difference in the wear scar as well and the usuability of polytron as a potential antiwear additive. The effects of the polytron on the wear rate are quite clear. Friction is substantially reduced and wear is eliminated up to which results in maximum equipment life, performance and oil and fuel economy. Polytron is compatible with all motor oils, gear oils, transmission fluids and other lubricants. This observation with polytron additive is quite contrary to the high wear rate results of Ferrante and Brainard [17], who observed thick reaction films with the popular ZDDP as an additive in a mineral oil base stock. And in a similar vein, the results of Godfrey [18], who studied TCP-white mineral oil base stock, indicates that their wear results are considerably higher than the results acquired by us.The observed value of the coefficient of friction in the presence of polytron is even an order of magnitude lower than the value observed by Mansot et al. [19] for nano-additives.

IV. CONCLUSIONS

This investigation in the effectiveness of the polytron as an antiwear additive in the base oil Helix permit the following conclusions.

1. The wear of the metal surface with the base lubricant was found to be approximately 75 micron. Upon the addition of polytron additive to the base oil, the surface scar of the metal showed a considerable decrease that can be related to the formation of a hard surface film introduced by polytron in the system.
2. In fact, the addition of 10 % by volume of polytron to the base oil reduced the value of wear to 25 micron indicative of one-third decrement in the wear.
3. The mass wear rate of the metal without the additive was estimated at 3.3×10^{-3} mg/min which, in the presence of polytron additive, decreased by an order of magnitude to the value of 8.33×10^{-4} mg/min.
4. An observation of the friction coefficient curves indicated that the value of friction coefficient is reduced to 0.004 by the addition of polytron to Helix.
5. When added to motor and transmission oils , polytron can dramatically reduce wear of the mating friction surfaces in car engines, transmissions and other equipment (*up to* 125%) and considerably extend their life span.

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REFERENCES

[1] D. I. Gittins, D. Bethell. D. J. Schiffrin and R. J. Nichols, "A Nanometre-scale Electronic Switch Consisting of a Metal Cluster and Redox-addressable Groups," *Nature,* vol. 408, no. 6808, pp. 67-68, 2000.

[2] V. N. Bakunin, A. Y. Suslov, G. N. Kuz'mina, L. M. Vedeneeva, O. P. Parenago, C. A. Migdal, P. E. Stott, A. V. Topchiev, "Surface-capped Molybdenum Sulphide Nanoparticles – A Novel Type of Lubricant Additive," *Lubrication Science*, vol. 16, pp. 207-214, 2004.

[3] H. M. Ghose, J. Ferrante, F.S. Honecy, "The Effect of Tricresyl-Phosphate (TCP) as an Additive on Wear of Iron (Fe)," *NASA TM-100103*, 1987.

[4] L. Quaroni, G. Chumanov, "Preparation of Polymer-coated Functionalized Silver Nanoparticles," *Journal of the American Chemical Society*, vol. 121, no. 45, pp. 10642-10643, 1999.

[5] T. Mandal, M.S. Fleming, D.R. Walt, "Preparation of Polymer Coated Gold Nanoparticles by Surface-confined Living Radical Polymerization at Ambient Temperature," *Nano Letters*, vol. 2, no. 1, pp. 3-7, 2002.

[6] S.P. Gubin, "Metal-containing Nanoparticles within Polymeric Matrices: Preparation, Structure, and Properties," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 202, no. 2, pp. 155-163, 2002.

[7] Z. Zhang, W. Liu, Q. Xue, "Study on Lubricating Mechanisms of La(OH)3 Nanocluster Modified by Compound Containing Nitrogen in Liquid Paraffin," *Wear*, vol. 218, no. 2, pp. 139-44, 1998.

[8] Z. S. Hu, J. X. Dong, "Study on Antiwear and Reducing Friction Additive of Nanometer Titanium oxide". *Wear*, vol. 216, no. 1, pp. 92-96, 1998.

[9] Z. S. Hu, J.X. Dong, "Study on Antiwear and Reducing Friction Additive of Nanometer Titanium Borate," Wear, vol. 216, no. 1, pp. 87-91, 1998.

[10] S. Chen, W. M. Liu, L.G. Yu, "Preparation of DDP-coated PbS Nanoparticles and Investigation of the Antiwear Ability of the Prepared Nanoparticles as Additive in Liquid Paraffin," Wear, vol. 218, no. 2, pp. 153-158, 1998.

[11] G. Socrates, Infrared Characteristics Group Frequencies, 2nd ed., John Wiley & Son , New York: 1994, pp. 97-112,.

[12] I. Minami, S. Mori, "Anti-wear Additive for Ester Oil," 14th International Colloquium Tribology, 2003.

[13] H. Kamimura, T. Kubo, I. Minami, S. Mori, "Effect and mechanism of additives for ionic liquids as new lubricants", Tribology International, vol. 40, no. 4, pp. 620-625, 2007.

[14] L. Du, B. Xu, S. Dong, H. Yang, W. Tu, "Study of Tribological Characteristics and Wear Mechanism of Nano-particle Strengthened Nickel-based Composite Coatings under Abrasive Contaminant Lubrication," *Wear*, vol. 257, pp. 1058 - 1063, 2004.

[15] N. Prasad, H. Sutar, S. C. Mishra, S. K. Sahoo and S. K. Acharya,"Dry Sliding Wear Behavior of Aluminium Matrix Composite Using Red Mud an Industrial Waste", *International Research Journal of Pure & Applied Chemistry*, vol. 3, no. 1, pp. 59-74, 2013.

[16] A. N. Suarez, M. Grahn, R. Pasaribu, R. Larsson, "The Influence of Base Oil Polarity on the Tribological Performance of Zinc Dialkyl Dithiophosphate Additives," *Tribology International*, vol. 43, pp. 2268-2278, 2010.

[17] W. A. Ferrante, "Wear of Aluminum and Hypoeutectic Aluminum-Silicon Alloys in Boundary-Lubricated Pin-on Disk Sliding," *NASA, TP-1442*, 1979.

[18] D. Godfrey, "Lubrication Mechanism of Tricresyl Phosphate on Steel," *ASLETrans*, vol. 8, no. 1, pp. 1-11, 1965.

[19] J. L. Mansot, Y. Bercion, L. Romana, J. M. Martin, "Nanolubrication," *Braz. J. Phys*, vol. 39, no. 1, pp. 51-75, 2009.

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