Engine Lubrication by UV Radiation

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Introduction

In automobile engines, the anti-wear additive zinc dialkyldithio-phosphate (ZDDP) is incorporated into lubricants to form surface films that protect piston-cylinder surfaces from rubbing. Although in use for over 70 years, the mechanism by which the ZDDP films form is unknown. Experiments show ZDDP films rapidly form submicron (~ 100 nm) thick irregular shaped pads of long polyphosphate chains separated from each other by regions of shorter chains. Currently, the ZDDP pads are thought [1] to form by high temperature thermochemical reactions with cross-linking induced by changes in zinc bonding at extreme pressures exceeding 150,000 bar.

Photochemical reactions differ by allowing the ZDDP pads to form by cross-linking of polyphosphate chains at relatively low temperature and pressure, but require a source of radiation. The proposed photochemical source is a consequence of QM where the pads are induced by QED to produce EM radiation at UV levels or beyond. QM stands for quantum mechanics, QED for quantum electrodynamics, EM for electromagnetic, and UV for ultraviolet. QM requires the submicron thick pads to have vanishing specific heat, and therefore frictional heat absorbed in rubbing cannot be conserved by an increase in temperature. Instead, conservation proceeds by the creation of QED photons at levels beyond the UV inside the ZDDP pads that allow pad formation by the photochemical cross-linking of polyphosphate chains.

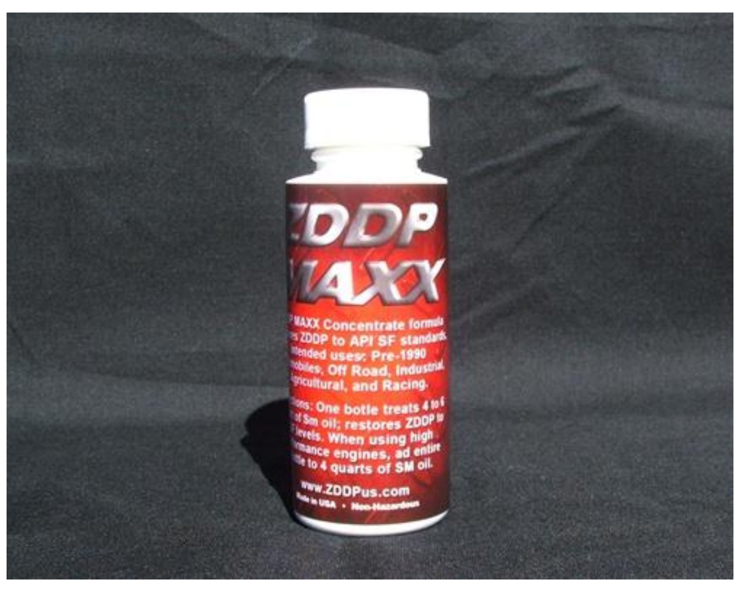
Tribology Tester

Ongoing development of a Tribology Tester with a UV source shown below is intended to show ZDDP films may form by cross-linking at ambient pressure and temperature by photochemical reaction, thereby avoiding the need for exotic cross-linking by changes in zinc bonding under extreme pressures.

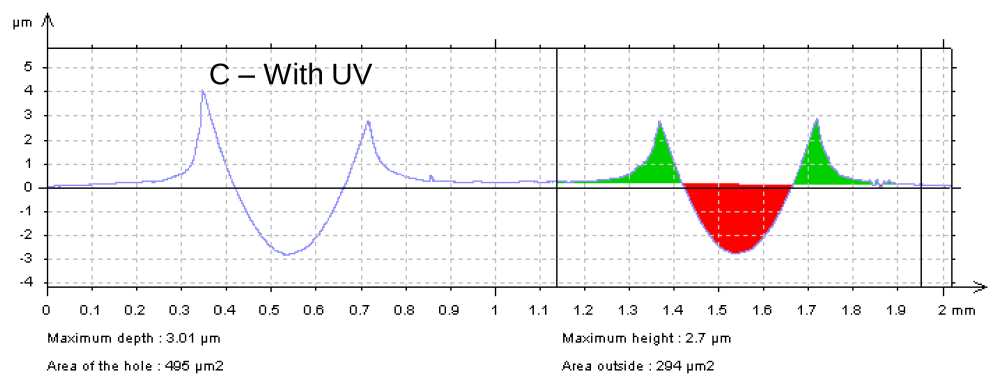
The top of a UV-C transparent window is rubbed by a steel cylinder with a thin film of oil and ZDDP in the interface. A UV-C lamp in the housing passes light through the window to the ZDDP film. The visualization of surface contact in the buried interface follows the notion [2] for profilometry of mechanically inaccessible contacts. After rubbing for 5-10 minutes, the window is removed and sent to the SEM for pad thickness measurements.

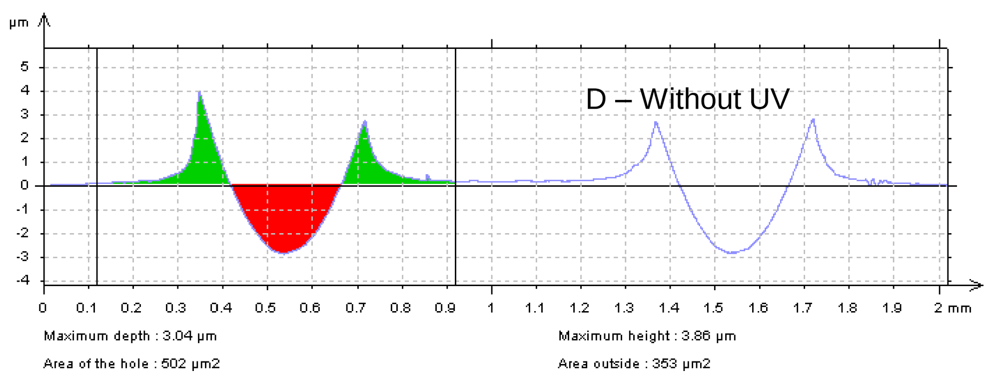
Progress Report

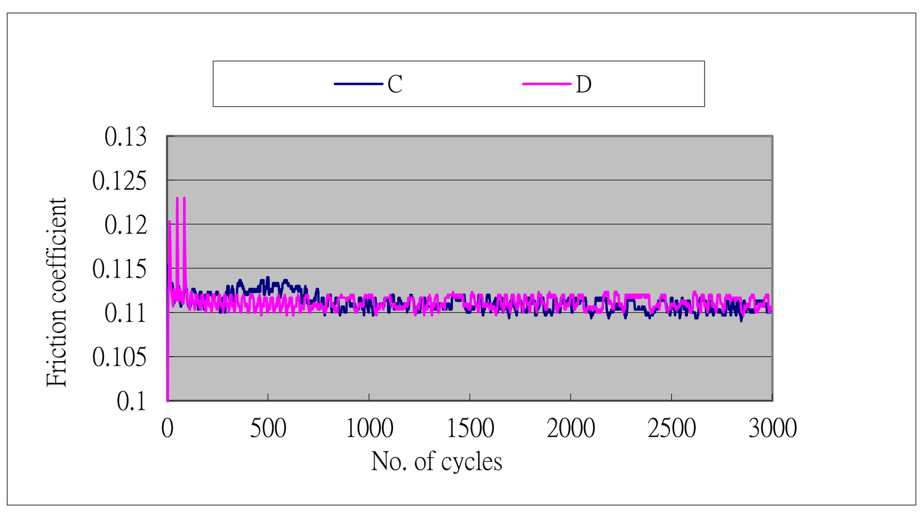
Preliminary ZDDP tests were made by the conventional Pin-on-Disk method prior to using the Tribology Tester. Instead of typical engine lubricant oil, Shell Ondina 68 oil [2] was used to allow comparison with earlier [3] work on profilometry in buried interfaces. Shell Ondina 68 is a paraffinic white oil [3] used for lubricating. compressors in food packaging applications, but not normally used in automobiles. The ZDDP pictured below is a product [4] of ZDDPlus$^{TM.}$



A carbon steel disk of HRC around 20 was used in this study. Shell Ondina 68 and ZDDP were mixed in a ratio of 5:1. The wear rate and friction coefficient are investigated for cases both with and without UV. The Pin-on-Disk test does not allow a convenient way to UV irradiate the surface of the oil during testing. The UV C lamp was removed from the Tribology Tester and positioned with the tip a few centimeters above the rotating disk. UV radiation was maintained for 30 minutes s prior to and during the test, a total of 1 hour. Although the time was limited, the same number of cycles and load were the same, and therefore differences in wear can be assessed to determine the UV effect. PGI images and friction coefficients designated by C and D correspond to the cases of with and without UV.







Conclusions

1. For Shell Ondina oil and ZDDP, the friction coefficient and wear area showed virtually no difference either with or without UV light.

2. UV aside, the friction coefficient for Shell Ondina with or without ZDDP did not show any significant difference. Wear tests were not conducted to establish the effects of ZDDP alone on Ondina. It is still not clear that ZDDP alone reduces the wear of the carbon steel disks.

3. Shell Ondina 68 oil is transparent to UV radiation at least in thin films. Combined with A680 fluorescent oil additive, the Ondina 68 provided visualization [5] of streamlines in flow tests over a bobsled model upon illumination with UV light. Hence, cross-linking of polyphosphate chains of ZDDP most likely did not occur in our tests because the UV was not absorbed by the Ondina oil.

Prognosis

The hypothesis that UV irradiation of lubricant oil reduces friction and wear is not supported by testing with ZDDP in Ondina 68. It is unlikely that further tests with more conventional automobile lubricants will alter this conclusion. UV absorption by an external source of UV radiation depends on the thickness of the oil that in submicron films will be small even if the oil is UV absorptive. Hence, the hypothesis that UV irradiation produced in 100 nm thick pads is the source of ZDDP that reduces friction and wear in rubbing may still be valid, but cannot be proven using an external source of UV radiation.

In the automobile engine, the UV radiation differs from that of external UV sources. The QED induced UV is created inside the 100 nm pads of polymers, and therefore is *a priori* absorbed allowing cross-linking to occur spontaneously at 100 % efficiency. However, the absorption efficiency of external UV is likely near zero percent. Unfortunately, there does not appear to be any way of testing for QED induced UV cross-linking in the pads other than in the automobile engine itself.

Future Testing

1. Without UV irradiation, repeat the Pin-on-Disk friction and wear tests on Ondina 68 with and without ZDDP. This is show if ZDDP does what it is advertised to do.

2. UV irradiate volumes (~100 ml) of Ondina 68 with and without ZDDP before the Pin-on-Disk tests. The thickness of the oil sample in the direction of the UV radiation should be 2-3 cm to avoid the film thickness limitation on absorption. Perhaps, a UV laser could be used instead of the lamps from the Tribology Tester. After UV conditioning, transfer the sample to the Pin-on-Disk set-up and repeat Test 1.

3. Investigate the possibility that cross-linking of ZDDP occurred by QED induced UV by SEM or experimental techniques using samples of used automobile oil. The question is whether the ZDDP cross-linking is caused by photolysis or by pressure and temperature?

Acknowledgment

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References

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