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Mechanisms of Varnish Formation and Implications for the Use of Soluble Varnish Removal Technology

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Varnish is an organic deposit produced by chemical degradation of mineral oil lubricants. Varnish can lead to numerous equipment problems including: filter plugging, restricted oil flow, poor heat transfer, valve sticking, fail-to-start conditions and unit trips.

As a consequence of the costly and prevalent nature of varnish-related failures, a number of studies have sought to elucidate the mechanism by which varnish forms. In all cases, oxygen is presumed to initiate oil breakdown through radical processes. These studies have focused upon the characterization of final oil oxidation products. In an effort to directly measure radical intermediates involved in thermo-oxidative lubricant degradation, we employed electron paramagnetic resonance (EPR) spectroscopy to gain additional insight into the mechanism of varnish formation.

The species observed by EPR spectroscopy suggest that oxygen plays a more significant role in the termination of radical processes than it does in their initiation. Even under anaerobic conditions, oil breakdown produces radicals. If these radicals are exposed to oxygen, polar, soluble varnish precursors form; these species eventually aggregate in the non-polar base oil matrix, forming insoluble varnish.

Numerous strategies for varnish removal have been developed. Most technologies focus on the removal of insoluble varnish particles by mechanical or electrostatic filtration. Unfortunately, these systems have no effect upon the polar soluble varnish precursors which arise when oil breakdown products are trapped by oxygen. Rather than simply filtering suspended particles, soluble varnish removal systems remove these soluble precursors by exploiting their unique chemistry. When these varnish precursors are removed, even lubricants exposed to extreme thermo-oxidative conditions show no propensity for varnish formation.

As a breakdown initiator, oxygen need only be present in catalytic amounts, however, as a radical trap, stoichiometric quantities are required for varnish formation to occur. Strategies aimed at controlling lubricant oxygen concentrations are, therefore, likely to further mitigate the risk of insoluble varnish formation in critical systems.

Topics: Lubrication, Case Studies in Tribology.

Preference: Oral presentation.