# Bridging the gap between nanoscale lubricant chemistry and its macroscale performance demonstrated by engine oils

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Lubricant performance suffers from aging through additive depletion, degradation products and contamination. Investigations have shown that, in addition to conventional oil parameters, it is also essential to detect such degradation mechanisms at the molecular level, e.g. by means of mass spectrometry, to establish reliable correlations with tribological behaviour. Based on engine oils from field studies and complementary laboratory experiments, it is demonstrated how additive degradation, soot and fuel dilution influence friction and wear.

**Keywords:** engine oil degradation mechanisms, additive depletion, soot, fuel dilution, mass spectrometry

## 1. Introduction

During operation, lubricants suffer from degradation due to prevailing operating conditions and entry of external contaminations. These factors limit the performance of lubricants and prevent them from fulfilling their tasks to the full extent in terms of functionality, efficiency, lifetime and reliability. Knowledge of degradation mechanisms is one key to adapt lubricants to their special field of application. Advanced analytical tools such as high-resolution mass spectrometry (MS) help to bridge the gap between oil degradation and its impact on friction and wear as demonstrated for engine oils [1,2]. A fully laboratory-based approach revealed relationships between the depletion of zinc dialkyl dithiophosphate (ZDDP) as antiwear additive, tribofilm composition and tribological properties. Consequently, field studies were carried out to verify or refine the obtained relationships between lubricant chemistry and lubrication performance in real applications. This contribution presents a combined approach of field and laboratory studies to systematically elaborate the correlations between engine oil degradation and its impact on friction and wear via the tribofilm composition.

## 2. Methods

To assess the tribological impact of antiwear additive depletion, soot formation and fuel dilution, a number of selected vehicles were regularly sampled in the course of an oil change interval to monitor engine oil degradation. Besides conventional analytical methods such as infrared spectroscopy, elemental analysis and viscometry, high-resolution MS was applied to describe the change in engine oil chemistry with increasing mileage. In addition, tribometer experiments were carried out on the Schwing-Reib-Verschleiß (SRV®) tribometer. On selected wear scars, the tribofilm composition was determined using X-ray photoelectron spectroscopy (XPS).

## 3. Results and discussion

It was found that ZDDP can rapidly degrade and form various organic and inorganic degradation products, dialkyl thiophosphate, dialkyl phosphates, phosphoric acid, and sulfuric acid, among others [3]. The presence of intact ZDDP and its degradation products, notably phosphoric and sulfuric acid, correlated with the oil's iron content. Lack of ZDDP and inorganic acids from ZDDP resulted in an increase in the wear rate, see Fig. 1.

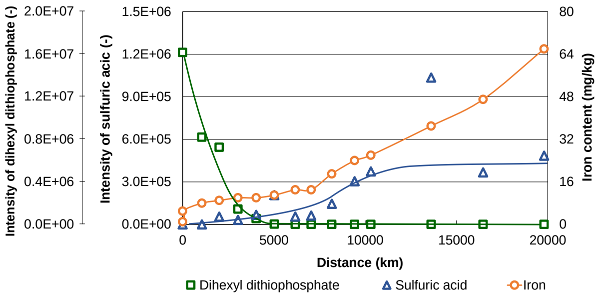


Figure 1: Progress of ZDDP, sulfuric acid as selected degradation product and iron content. Modified from [3].

Soot and fuel dilution also contributed to increased wear. Besides reduction in viscosity that deteriorates film thickness, fuel in engine oil seemed to accelerate ZDDP degradation. SRV experiments confirmed the findings from the field and showed how oil chemistry influenced tribofilm composition, which in turn had its impact on friction and wear. The presented approach, especially high-resolution MS, enabled reliable correlations between nano-scale processes and macro-scale phenomena.

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## 5. References

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