



# Automotive Lubricant Testing and Additive Development

Simon Tung,  
Bernard Kinker,  
and Mathias Woydt

---

Editors

# STP 1501



**STP 1501**

# ***Automotive Lubricant Testing and Advanced Additive Development***

*Dr. Simon Tung, Mr. Bernard Kinker, and Dr. Mathias Woydt, editors*

ASTM Stock Number: STP1501



ASTM  
100 Barr Harbor Drive  
PO Box C700  
West Conshohocken, PA 19428-2959

Printed in the U.S.A.

## Library of Congress Cataloging-in-Publication Data

Automotive lubricant testing and additive development / Simon Tung, Bernard Kinker, and Mathias Woydt, editors.

p. cm. — (ASTM stock number: STP1501)

**ISBN:** 978-0-8031-4505-4

1. Automobiles--Motors--Lubrication systems. 2. Automobiles--Lubrication. I. Tung, Simon. II. Kinker, Bernard, 1945- III. Woydt, Mathias, 1963- IV. ASTM International.

TL214.O5A98 2008

629.25'5--dc22

2007051559

Copyright © 2008 AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

## Photocopy Rights

**Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by the American Society for Testing and Materials International (ASTM) provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923; Tel: 978-750-8400; online: <http://www.copyright.com/>.**

## Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM International Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

Printed in Mayfield, PA  
April, 2008

## Foreword

---

This publication, *Automotive Lubricant Testing and Advanced Additive Development*, contains peer reviewed papers from the above symposium, organized by committee D02, in December, 2006 at Lake Buena Vista, Florida. This symposium was in conjunction with the D02 sub-committee "Fuels and Lubricants". The symposium Co-Chairs were Dr. Simon Tung, General Motors, Warren, MI, Mr. Bernard Kinker, Rhomax, USA, Horsham, PA, and Dr. Mathias Woydt, BAM, Federal Institute for Materials Research and Testing, Berlin, Germany.



# Contents

---

<b>Overview</b>	vii
<b>A Review of Engine Oil Oxidation Bench Tests and Their Application in the Screening of New Antioxidant Systems for Low Phosphorus Engine Oils—V. GATTO, W. MOEHLE, E SCHNELLER, T. BURRIS, T. COBB, AND M. FEATHERSTONE</b>	1
<b>Viscometric Temperature Sensitivity of Engine Lubricants at Low Temperature and Moderately High Shear Conditions—K. O. HENDERSON AND C. P. MAGGI</b>	14
<b>No/Low SAP and Alternative Engine Oil Development and Testing—M. WOYDT</b>	35
<b>Synergistic Tribological Performances of Borate Additive in Lubricants—J.-Q. HU, Y.-Q. HU, G.-L. LIU, AND Y.-H. MA</b>	48
<b>The “Practice Relevant Pitting Test”—A New Improved Test Method to Evaluate the Influence of Lubricants on the Pitting Load Capacity of Case Carburized Gears—B.-R. HOHN, P. OSTER, T. RADEV, AND T. TOBIE</b>	57
<b>ROBO—A Bench Procedure to Replace Sequence IIIGA Engine Test—B. G. KINKER, R. ROMASZEWSKI, AND P. A. PALMER</b>	66
<b>Mechanochemical Additive-Assisted Reconditioning Effects and Mechanism on Worn Ferrous Surfaces —J. YUANSHEG, Y. HE, AND L. SHENGHUA</b>	79
<b>Study of the ZDDP Antiwear Tribofilm Formed on the DLC Coating Using AFM and XPS Techniques—T. HAQUE, A. MORINA, A. NEVILLE, R. KAPADIA, AND S. ARROWSMITH</b>	92
<b>Validation of Oxidative Stability of Factory Fill and Alternative Engine Oils Using the Iron Catalyzed Oxidation Test —E. FITAMEN, L. TIQUET, AND M. WOYDT</b>	103
<b>Additive and Base Oil Effects in Automatic Particle Counters—P. W. MICHAEL, T. S. WANKE, AND M. A. MCCAMBRIDGE</b>	109
<b>Design of Functionalized PAMA Viscosity Modifiers to Reduce Friction and Wear in Lubricating Oils—M. MÜLLER, J. FAN, AND H. SPIKES</b>	116
<b>Surface Characterization Techniques in Wear of Materials—K. MIYOSHI, K. ISHIBASHI, AND M. SUZUKI</b>	126



# Overview

---

This book represents the work of several authors at the 1<sup>st</sup> Symposium organized by D02 to focus on automotive lubricant testing and advanced additive development. This symposium was held at Lake Buena Vista, Florida, in conjunction with the meeting in December 2006 of the ASTM D02 sub-committee “Fuels & Lubricants”.

In order to help automotive industry meet lower emission standards, higher fuel economy goals, and longer drain intervals associated with a minimization of any adverse effects of lubricants to the environment, the petroleum industries and the additive suppliers are developing low SAPS (sulfated ash, phosphorus and sulfur) and high tribological performance lubricants to meet these challenges. New developments in powertrain system design and advanced additive formulation are essential in addressing these problems. This ASTM symposium has provided an outstanding forum to discuss how OEMs and lubricant companies are solving real engineering problems to increase fuel economy and meet emissions legislation together. This symposium publication is focused on both the chemical and tribological aspects of the functional performance of automotive lubricant and testing. In this symposium, recent advances in additive and base oil chemistry and function have been covered in details; product formulation for engine performance and the link between additive chemistry and emissions have been discussed. Tribological performance issues such as fuel economy retention, wear protection and friction reduction as well as their retention over drain, engine durability, and future challenges, including advanced powertrain developments, new lubricant test methods outside of the application, lubricant formulations, and correlation between lubricant formulation and engine performance are the key subjects.

Papers and presentations are targeted to provide a comprehensive overview of various lubrication test methods for a typical engine system including the oxidation tests for screening antioxidants and base oils, bench wear tests, engine sequence test development, and oil condition monitoring techniques, as well as the major technical issues on lubricant degradation and the surface mechanisms of ZDDP tribofilms interacted with advanced DLC coatings.

Several papers describe the low SAP lubricant development and testing, the impact of additive and base oil on engine oil characteristics, the current industrial standard tests methods for lubricant oxidation stability, surface pitting, and alternative engine oil development. Some of the papers discuss the synergistic effects of lubricant additive formulation and surface coatings while others concentrated on the coverage of various surface engineering applicators in practice. This particular surface engineering area continues to be the major activity of many industrial researchers.

As in the past ASTM lubricant symposium lubricant formulation technology was always a critical focus theme. This ASTM symposium was no exception. The diversity demonstrated in this symposium exemplified the critical role of the lubricant formulation issues which was influenced by recent automotive hardware changes. Papers ranged from a discussion of low SAP lubricants and validation of oxidation stability for factory fill and alternative engine oils used in new automotive emission system. Impact of emission regulations and hardware changes on lubricant formulations also was discussed this symposium. In addition, the additive development addressing surface interaction studies between advanced materials and lubricants plays an important role for automotive hardware changes.



On the behalf of all editors and chairs, we would like to thank the outstanding contributions from all authors and speakers in this symposium for making our 1<sup>st</sup> automotive lubricant testing and additive development symposium very successful. Thank you for your participation. We hope we will organize another symposium in the near future.

*Dr. Simon Tung*  
General Motors  
Warren, MI

*Mr. Bernard Kinker*  
Rhoxmax, USA  
Horsham, PA

*Dr. Mathias Woydt*  
BAM, Federal Institute for Materials Research and Testing  
Berlin, Germany



[www.astm.org](http://www.astm.org)

ISBN: 978-0-8031-4505-4

STOCK #: STP1501