Automotive Lubricants and Testing

Simon C. Tung and George E. Totten, EDITORS

ASTM Stock Number: MNL62
Contents

Introduction ............................................................................................................................ v

Part 1: Automotive Tribology and Lubrication Fundamentals .............................................. 1
Chapter 1—Fundamental Principles of Contact and Lubrication ........................................ 3
  Q. Jane Wang, Herbert S. Cheng
Chapter 2—Automotive Lubricants .................................................................................... 23
  Derek Mackney, Nick Clague, Gareth Brown, Gareth Fish, John Durham
Chapter 3—Lubricant Properties and Characterization ................................................... 47
  Kenneth O. Henderson, Chris J. May
Chapter 4—Controlling Lubricant Degradation through Performance Specification .......... 61
  Malcolm F. Fox
Chapter 5—Elastohydrodynamic Lubrication Film Tests and Tribological Bench Tests ......... 85
  Q. Wang, Simon C. Tung, Y. Liu, Y. Zhang, D. Zhu
Chapter 6—Automotive Engine Hardware and Lubrication Requirements ......................... 105
  Edward P. Becker, Simon C. Tung

Part 2: Automotive Lubricant Testing, Lubricant Performance, and Current Lubricant Specifications .................................................................................................................. 117
Chapter 7—Gasoline Engine and Diesel Engine Powertrain Systems .................................. 119
  P. Silva
Chapter 8—Automotive Bearing Systems—Journal Bearings .............................................. 129
  Omar Mian
Chapter 9—Testing and Evaluation of Lubricating Greases for Rolling Element Bearings of
  Automotive Systems ........................................................................................................... 137
  Xinglin Li, Can Wu, Baojie Wu, Hongyu Zhang, Jianbin Luo, Qiang Feng
Chapter 10—The Drivetrain System .................................................................................... 157
  Dave Simner
Chapter 11—Gear Oil Screen Testing with FZG Back-to-Back Rig .................................... 177
  Klaus Michaelis, Brian M. O'Connor
Chapter 12—Problems and Opportunities Regarding the Lubrication of Modern Automotive Engines ......................................................................................................................... 191
  E. S. Yamaguchi, G. A. Tanaka, K. Matsumoto
Chapter 13—Bench Performance Test Methods for Lubricated Engine Materials ................ 215
  Peter Blau, Simon C. Tung
Chapter 14—Current and Future Specification of Lubricant Performance ............................ 231
  Malcolm F. Fox
Chapter 15—Automatic Transmission Lubricants ............................................................... 255
  Richard J. Vickerman, Craig Tipton
Chapter 16—Other Automotive Specialized Lubricant Testing Including Manual Transmission,
  Rear Axle, and Gear Box Lubricant Testing and Specification ......................................... 273
  Dave Simner
Chapter 17—Design for Reduced Wear ............................................................................... 293
  Roger Lewis, Tom Slatter
Chapter 18—Nonpetroleum-Based, No/Low-Sulphur, Ash, and Phosphorous, and Bio-No-Toxicity
  Engine Oil Development and Testing ................................................................................ 317
  Mathias Woydt

Part 3: Specialized Automotive Lubricant Testing and Future Automotive Applications .......... 331
Chapter 19—Current and Future Advances in Materials Development for Tribological Applications ......................................................................................................................... 333
  Barbara Rivolta, Lauralice Canale
Chapter 20—Surface Analysis and Tribochemistry of Automotive Engine Components ........................................... 351
Ardian Morina, Hongyuan Zhao

Chapter 21—Tribology and Fine Automotive Mechanical Systems ................................................................. 379
Werner Friedrich Stehr

Chapter 22—Analysis of In-Service Automotive Engine Oils ................................................................. 399
Jim C. Fitch

Chapter 23—Diesel Fuel Lubrication and Testing ...................................................................................... 417
Jun Qu

Chapter 24—Filters and Filtration Testing of Automotive Fuels and Lubricants .............................................. 427
Gary Bessee, Erica Clark-Heinrich

Chapter 25—Dynamic Friction Characterization and Modeling of Tripod Constant Velocity Joints ............... 437
Chul-Hee Lee, Andreas A. Polycarpou

Chapter 26—Biobased Automotive Lubricants ...................................................................................... 455
Lou A. Honary

Appendix: List of Referenced Documents ...................................................................................... 469
Index ........................................................................................................................................ 481
Introduction

The automotive and petroleum industries are facing difficult international competition, government regulations, and rapid technological changes. Ever-increasing government regulations require improved fuel economy and lower emissions from automotive fuel and lubricant systems. Higher energy-conserving engine oils and better fuel-efficient vehicles will become increasingly important with increasing emphasis on saving resources and reducing engine friction. Identification of industry research needs for reducing friction and wear in transportation are critical for improving fuel economy and extended vehicle reliability. There are hundreds of tribological components, from bearings, pistons, transmissions, and clutches, to gears and drivetrain components. The application of tribological principles is essential for motor vehicle reliability and energy conservation.

Automotive Lubricants and Testing will provide a comprehensive overview of various lubrication aspects of a typical powertrain system, including the engine, transmission, driveline, and other components, and will address major issues and the current development status of automotive lubricant test methods. In North America, engine design engineers and tribologists are constantly challenged to create innovative products that meet more demanding emissions and fuel economy targets. Current research and development on engine cylinder components include new designs, materials, coatings, and surface treatments with the goals of weight reduction, longer life, higher operating temperatures, and reduced friction. To assist the automotive industry in achieving lower emission standards, higher fuel economy, and longer drain intervals, the petroleum industries and additive suppliers are developing low-SAP (sulphur, ash, and phosphorous) fuels and higher fuel-efficient performance lubricants.

Automotive Lubricants and Testing covers lubrication fundamentals and lubricant testing methods that are influenced by lubricant additive formulation and engine hardware changes. There are few existing publications that provide such a correlation between test methods and lubricant formulation technology. The most current ASTM specifications and all current International Lubricant Standards Advisory Committee approval systems for automotive engine lubricants are included in this text. In addition, current standard test methods for automotive lubricants and the other bench test methods or test simulations developed for the powertrain system are reviewed. Although much of this handbook is focused on powertrain systems and engine lubricants, other automotive lubricants such as transmission oils, chassis lubricants, gear lubricants, and lubricating greases are also covered. Tribological bench test methods and automotive specialized lubricant testing to be used in a laboratory or mechanical devices for simulation of engine or powertrain system operating conditions are also described.

The lubricant in a powertrain system is subjected to very complex wear conditions in different parts of the engine. These conditions are due to variable patterns of driving behavior and lubricant contamination by reactive combustion gases and particulates that create difficulties in the correlation of actual engine/lubricant performance with simple bench tests. Therefore, a key feature of engine oil development and testing is the use of real engine tests to assess lubricant behavior in the complex combination of conditions present in an engine. Automotive Lubricants and Testing also covers the major test methods for typical engine components (gasoline and diesel), engine oil characteristics, engine material evaluations, and the current industrial standard test methods for chassis and drivetrain systems. Included are detailed descriptions of the tribological testing challenges associated with various automotive engine components, service effects on automotive lubricants, standard bench and engine sequence test development, and updated engine oil specifications for gasoline and diesel engine lubricants.

This handbook contains 26 chapters covering the powertrain, transmission, chassis, and drivetrain systems. In addition, the advanced lubrication and tribochemistry of powertrain systems have been included, such as diesel fuel lubrication, specialized automotive lubricant testing development, and biodegradable automotive lubricants. In addition, we have generated an appendix that includes abbreviations and technical terms, all ASTM reference documents, and updated standard test methods for engine oils, transmission lubricants, gear lubricants, and grease.

Simon C. Tung and George E. Totten, Editors
Dr. Simon C. Tung has become an internationally recognized leader in the field of tribology and lubrication engineering as a result of 26 years of industrial applied research and project management with General Motors and through his service to the tribology technical community. Tung has been involved in the original engine manufacturers (OEM) and automotive industry since joining General Motors Research laboratories in 1982. While there he led pioneering research and development on automotive powertrain tribology and lubrication engineering and was appointed a technical fellow at the General Motors Research and Development Center in 2003. In 2008, he joined the Industrial Technology Research Institute (ITRI) as General Director, where he was responsible for managing all research and development programs in the green energy and environmental research laboratories. He made significant contributions in the research areas of green energy, energy storage systems, hydrogen energy, energy efficient fuels and lubricants, and greenhouse emissions reduction. Dr. Tung’s technical expertise includes energy technology, environmental engineering, lubrication, and automotive systems. He has over 180 published works and holds more than 30 U.S. and international patents on novel methods of improving energy efficiency and environmental protection.

Dr. Tung has received many distinguished honors, including being named Fellow of the Society of Automotive Engineers (SAE) and Fellow in the Society of Tribologists and Lubrication Engineers (STLE), as well as receiving the highest honor of Gold Award from the Engineering Society of Detroit (ESD). In addition, he has received 25 professional outstanding achievements awards during his career. He was recently honored with SAE International’s Edward N. Cole Award for Automotive Engineering Innovation during the SAE 2011 World Congress.

In August 2011, Dr. Tung was appointed the global OEM industry liaison manager by R.T. Vanderbilt. In this new capacity, Dr. Tung leads global OEM liaison activities by developing and disseminating global OEM advanced lubricant requirements and energy resources technologies. In addition, he assists in advancing tribology and lubricant technology programs at R.T. Vanderbilt. He is also responsible for developing methods and providing technical input for the testing and evaluation of fuel efficient lubricant products for potential commercialization.

Dr. Tung holds a Ph.D. in chemical engineering from Rensselear Polytechnic Institute. He also received an MBA from University of Michigan-Ann Arbor.

Dr. George E. Totten is president of G.E. Totten & Associates, LLC, a research, sales, and consulting firm specializing in thermal processing, industrial lubrication problems, and equipment supply. In addition, he is a visiting professor at the University of Sao Paulo, an adjunct professor at Texas A&M University, and a research professor at Portland State University. Until his retirement in 2001, Dr. Totten was a senior research scientist at Union Carbide Corporation, where he was responsible for their research and development programs in metalworking quenchants, hydraulic fluids, and exploratory research programs in lubrication fundamentals. Dr. Totten is the section chairman of ASTM D02 L.06 on Non-Lubricating Oils and is a member of the ASTM committee on publications.


Dr. Totten received B.S. and M.S. degrees in chemistry from Fairleigh Dickinson University in New Jersey and a Ph.D. in physical organic chemistry from New York University. Dr. Totten is past president of the International Federation for Heat Treatment and Surface Engineering (IFHTSE), a fellow of ASM International, SAE International, and IFHTSE, and a founding fellow of AMME (World Academy of Materials Manufacturing Engineering). Currently, Dr. Totten is the co-editor of ASTM’s Journal of Materials Performance and Characterization (MPC) with Professor Richard Neu.