

ExxonMobil

Lubrication Fundamentals

Third Edition, Revised and Expanded

Don M. Pirro | Martin Webster | Ekkehard Daschner



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Preface

Lubrication and the knowledge of lubricants are not only subjects of interest to all of us, but they are also critical to the cost-effective operation and reliability of machinery that is, directly or indirectly, part of our daily lives. Our world, and exploration of regions beyond our world, depend on mechanical devices that require lubricating films. Whether in our homes or at work, whether knowingly or unknowingly, we all need lubricants and some knowledge of lubrication. Home appliances, lawnmowers, bicycles, and fishing reels are a small sampling of devices that have moving parts that require lubrication. The millions of automobiles, trucks, buses, motorcycles, airplanes, ships, and trains depend on lubrication for operation, and it must be effective lubrication for dependability and safety, and to reduce the environmental impact.

Many changes in the field of lubrication have occurred since the second edition of *Lubrication Fundamentals* was published in 2001. Today, intricate and complex machines are used to make paper products; huge rolling mills turn out metal ingots, bars, and sheets; metalworking machines produce very high precision parts; and special machinery is used to manufacture cement, rubber, and plastic products. Emission regulations have had a major impact on all transportation and power generating equipment and the lubricants that protect them. The use of computers, robotics, and higher technology has led to advanced machine designs that result in faster machine speeds, greater load-carrying capability, more compact equipment, smaller capacity lubricant reservoirs, higher machine temperatures, various material compatibility challenges for lubricants, restrictions in lubricant additive content, and less frequent lubrication application up to and including fill-for-life lubrication. As a result, there continues to be an explosion in higher performance and specialty application oils and greases. The impact of these lubricants on our natural environment is also a driver for new lubricant technology.

The third edition of *Lubrication Fundamentals* builds on the machinery basics discussed in the first two editions, much of which is still very applicable today. The third edition also addresses many of the new applications, and new lubricant and base stock technologies that were introduced or improved upon in the past 15 years to meet the needs of modern machinery and sustainability. The lubricants industry will continue to be faced with many challenges going forward, and innovative technologies will be needed to meet these challenges. Critical activities along the lubricant value chain that are impacted by technology include new lubrication requirements, crude oil composition and selection, base stock manufacture, product formulation and evaluation, lube oil blend plant capabilities, lubricant application, and environmental stewardship. These will be exciting times for industry, especially those participating in the quest to develop the new lubricant molecule for the future.

Don M. Pirro
Martin Webster
Ekkehard Daschner

Acknowledgments

Lubrication Fundamentals, Third Edition Revised and Expanded, like many technical publications of this magnitude, is not the work of one or two people. It is the combined work of hundreds of engineers, chemists, scientists, physicists, technologists, designers, writers, and artists—a compendium of a broad spectrum of skills and talent over a long period. The study of lubrication fundamentals starts with the scientists who research the interaction of oil films with moving components under various stresses and loads. It then takes the unique cooperation that exists between the machine designer and equipment builders, on one side, and the lubricant formulators and suppliers on the other. Additionally, collaboration often takes place with many industry associations such as the International Organization for Standardization, American Society for Testing and Materials, American Petroleum Institute, Association des Constructeurs Européens d'Automobiles, Society of Automotive Engineers, Society of Tribologists and Lubrication Engineers, Deutsches Institut für Normung, National Lubricating Grease Institute, and American Gear Manufacturers Association. This frequently culminates in the mating of the right lubricant properly applied to meet the requirements of the most efficient and demanding machines operating today.

The lubricants industry is most grateful to lubrication pioneers such as J. George Wills, the author of the first edition who identified the need for a practical resource on lubrication. He developed a vision, secured the support and resources to undertake such a monumental task, and then dedicated the effort to turn his vision into reality. We are also most appreciative for the efforts of A.A. (Al) Wessol, who was the coauthor of the second edition. Al was a true lubrication expert in many applications and was willing to share his knowledge and years of practical experience. We are privileged to be able to build on their efforts and share the many technological advances in industry.

It would be impossible to list the host of people who have helped to put this third edition together. The book compiles the many technical publications of ExxonMobil and the cooperative offerings of the foremost international equipment builders and associations. We are most appreciative to the many original equipment manufacturers and industry associations, with whom we have worked over many years, for sharing their knowledge and technology.

We thank the following senior managers at ExxonMobil Research and Engineering for their acceptance, support, and encouragement for this project: Grant Karsner, Michele Touvelle, Nick Hilder, and Bill Buck. Additionally, we recognize Jane Walter of ExxonMobil for her assistance with the book cover design and graphics.

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Ekkehard Daschner is the Industrial Lubricant Section Head and Greases Technology Program Lead at ExxonMobil Research and Engineering, Paulsboro, New Jersey. Daschner earned his mechanical engineering degree in Germany and started his career in an aluminum company. In 1982, he joined the Mobil Oil AG R&D laboratory in Germany supporting product development projects. After holding various positions in technical support, he was appointed Area Sales Director and Brand Manager in Germany and the European headquarters in London and Brussels, and later served as European and later as Global Industrial and Marine Equipment Builder Services Manager. He is recognized as an expert in lubricant applications and in particular in bearings and gearboxes.

Martin Webster is a senior research associate at ExxonMobil Research and Engineering, Annandale, New Jersey. He earned his BS and MS in aeronautical engineering and his PhD in tribology from Imperial College, London, UK. In 1986, he was awarded the Bronze Medal in tribology from the Institute of Mechanical Engineers in the UK. After spending 4 years working in the UK, he joined ExxonMobil in 1989. At ExxonMobil, Martin has held various positions in research and product development and is currently involved in the study of fundamental lubrication mechanisms at the company's Corporate Strategic Research Laboratory. His publications include peer-reviewed papers, book chapters, and patents in elastohydrodynamic lubrication (EHL), rolling contact fatigue, hydrodynamics, contact mechanics, and wear. His industry activities have

included membership in the American Society of Mechanical Engineers (ASME) bearings committee and the American Gear Manufacturers Association (AGMA) gear rating committee. He has been a member of the STLE since 1989. In 2006, he was elected a director of the STLE and in 2012 he joined the executive committee. He is currently serving a 1-year term as the STLE president in 2015–2016.

ExxonMobil Contributors to the Third Edition

We would like to acknowledge contributions to the third edition from the following ExxonMobil engineers, chemists, lubricant formulators, tribologists, scientists, and technologists. Collectively, these people represent over 600 years of lubrication experience. They are not only leading experts within ExxonMobil, but many of them are recognized as among the best lubrication experts in industry:

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