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Recent Developments in Wear Prevention, Friction and Lubrication, 2010:
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PREFACE

The knowledge gained from studies on *friction*, *lubrication* and *wear* of contacting surfaces (three terms collectively known as *tribology*) is met in every branch of engineering. Tribology is a multidisciplinary science involving mechanical engineering, materials and lubrication science, physics, and chemistry. Tribological principles are normally used in characterising the mechanical behaviour of surfaces in relative motion. This involves a very large number of applications ranging in size from the nano-scale (molecular and nano-tribology) to the macro-scale (bearings, tyres, rock drills, etc.).

Friction, lubrication and wear are inherent characteristics of the physical world regardless of scale. From the intermolecular forces holding a gecko's feet on a vertical wall to the tractive forces at the contact patches of aircraft tyres; from the lubricating film at the rolling contact of a ball on a rolling-bearing raceway to the soft magma supporting tectonic plates of the earth; from the erosion of human teeth from toothpaste particles to the particle erosion of turbine blades; such diverse phenomena can be described and analysed in tribological terms.

Every type of machinery includes parts affected by friction, lubrication, and wear. Therefore, the role of tribology in machine operation and reliability is a major one. As a result, the effect of tribology to modern world economy, even though unknown to the majority of the population, is crucial. Although the effect on the economy has been quantified and found to represent a significant proportion of the gross domestic product of economically advanced countries, the true effect pertaining to the development of technologically advanced products is far greater and not immediately obvious.

There are several good books on tribology covering the fundamental theory and various applications. However, technology is progressing at an immense pace and engineering norms are quickly outdated. This book is based on the collective experience of some of the world's top experts on friction, lubrication and wear. It presents recent developments in the field of tribology and its contributors are equally divided among theoreticians and experimentalists. Furthermore, some chapters contain new theory and results, which, in the editor's experience, is at the frontier of research. The topics covered in the eight chapters of this book include

thin-film lubrication from a theoretical perspective, a critical review of rolling-bearing life-prediction models, a review of Laser Surface Texturing, a proposed unification of friction and wear via thermodynamic principles, the role of tribofilms in concentrated contacts from a materials-science perspective, transient phenomena in elastohydrodynamic lubrication from an experimental point of view, a theoretical assessment of the Stribeck curve in lubricated contacts, and, finally, a thorough presentation of modelling and adhesion problems of microelectromechanical systems (MEMS) and miniature devices.

Chapter 1 by Professor Szeri is an in-depth discussion of the "thin-film" lubrication theory referring to hydrodynamic and elastohydrodynamic lubrication. Professor Szeri (University of Delaware, USA), a well-known author with many decades of research experience, attempts to define the limits of the classical Reynolds' theory of lubrication in both laminar and turbulent flows of liquids and gases. He discusses the continuity limitation of the classical theory in terms of film thickness, wall slip, and the Reynolds number. He reaches to quantitative conclusions on the validity of the film continuity assumption and the necessity to use the full Navier-Stokes equations or "first principles" in some applications for which the Reynolds' theory is inaccurate.

Chapter 2 by Dr Zaretsky is a critical evaluation of the main models proposed for the prediction of the fatigue lives of rolling-element bearings, comprising the past and present ISO standards. Those models have been adopted by major bearing manufacturers such as SKF and include the classical work of Palmgren, Weibull, Lundberg, Ioannides, Harris, and Zaretsky. Dr Zaretsky, a Chief Engineer of NASA and Adjunct Professor at Case Western Reserve University (USA), is an authority on bearing life prediction. In his comprehensive tutorial, which is suitable both to experts and non-experts on this topic, he explains the advantages and disadvantages of the various models from a theoretical point of view, and includes a selection of endurance test results to compare the relative accuracy of the theoretical models. Among Dr Zaretsky's conclusions is that the load-life exponent (10/3) used in the ANSI/ABMA and ISO standards to predict rolling bearing life is not reflective of modern rolling bearings and actually underestimates bearing lives.

Chapter 3 by Professor Etsion is a review of Laser Surface Texturing (LST). Surface texturing of tribological, mechanical components, has emerged in the last decade as a viable option of surface engineering resulting in significant improvements in load capacity, wear resistance, reduction of friction etc. Professor Etsion (Chair in Fluid Mechanics and Heat Transfer, Technion – Israel Institute of Technology) is one of the most recognised experts on the topic of surface texturing. In his review of the LST, he outlines the technique and discusses the potential of this technology in various engineering applications, including

automotive (piston rings), bearings, seals, magnetic storage devices (hard disk sliders and magnetic tapes), and others.

Chapter 4 by Professor Bryant is rather unique in the literature. Professor Bryant, a professor in the University of Texas at Austin (USA) and the Editor of the Journal of Tribology of the American Society of Mechanical Engineers, attempts to unify friction and wear via thermodynamic principles, focusing on the dissipative processes found at sliding interfaces. He presents a review of friction and wear mechanisms, and relates them in terms of their associated thermodynamics, energy losses and entropy produced by common dissipative processes. He shows that the expressions for entropy generation in dissipative processes operative at a sliding interface, which are common to both friction and wear, could result in unified friction and wear models.

Chapter 5 by Professors Jacobson and Hogmark provides an overview of the role of tribofilms on surfaces in sliding contacts. The authors, both professors of materials science and tribology at Uppsala University in Sweden, have several decades of research experience on such topics. Through illustrative examples based on real applications, they show that tribologically induced surface modifications result in the creation of surface layers or tribofilms ranging in thickness from a few nanometres to tens of micrometres. The surface modifications include topographical changes, formation of micro-cracks, material phase transformations, formation of oxides, formation of solid films by reaction with lubricant additives, material transfer from the counter surface, etc. It is such tribofilms that actually dominate the contact properties between sliding solids in terms of friction and wear and not the original materials.

Chapter 6 by Dr Glovnea, Reader in the School of Engineering and Design at Sussex University in England, presents a review of recent experimental research on non-steady-state elastohydrodynamic lubrication, including transient loading, sudden variation of entrainment speed and variation of micro-geometry. His study is relevant to all industrial machinery involving lubricated contacts and susceptible to vibrations or normal operation involving load and speed variations. Dr Glovnea, who has spent several years studying such phenomena in the Tribology Group of Imperial College London, shows how transient conditions and various parameters affect (normally sub-micrometre) elastohydrodynamic films, their thickness distribution and overall cohesion. It is thus possible to assess the risk of contact damage from film thinning or collapse.

Chapter 7 by Professor Khonsari (Louisiana State University, USA) and Dr Booser, both well-respected researchers in the tribology community and authors of best-selling tribology books, deals with the different lubrication regimes met in contacts at relatively low sliding

speeds. These are related via the so-called Stribeck curve, which demonstrates the transition from boundary lubrication at the start-up of motion to mixed lubrication as the speed is increased, and on to full-film lubrication at higher speeds. The review covers issues pertaining to roughness asperity interactions (particularly in the mixed lubrication regime), wear, stick-slip phenomena, and the effects of lubricant additives.

Chapter 8 by Dr Xue (Analog Devices, Inc., USA) and Professor Polycarpou (University of Illinois at Urbana-Champaign, USA) covers microelectromechanical systems (MEMS) from an experimental and theoretical point of view. The authors have extensive experience in this research field and are focused on the problem of adhesion or stiction of MEMS and miniature devices, which reduces their reliability and hinders their advancement and wider commercialisation. They develop an experimentally validated, adhesive-contact model, which is valid for a wide range of adhesion parameter values, covering the practical range of application of MEMS and other miniature devices.

The editor embarked on this project in June 2007 and invited eminent tribologists to make contributions on specific topics based on the editor's plans for the book. The project was completed in about 18 months before the manuscripts were sent to the publisher. The editor is grateful to the authors/contributors of this book for their cooperation and patience throughout the lengthy process of communication, chapter editing, and book compilation. The editor is also grateful to the expert reviewers (see the list of reviewers) who kindly reviewed the chapters, one chapter each reviewer. Finally, the editor would like to thank the publisher, Research Signpost, for the original invitation and kind assistance.

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