Preface

The important prerequisites of any engineering system are its reliability, efficiency, and long life. Relative sliding movement between the two components in an engineering system causes a loss of the material from the surfaces of both the components, and this loss, termed as wear, may affect its reliability, efficiency and long life. In most of the situations, the failure of the machines is due to the wear and not due to the breakage of component. Wear is not an intrinsic property of a material but a characteristic of an engineering system. Wear is rarely catastrophic, but it reduces the operating efficiency and increases power losses, oil consumption, and component replacement rates. It, therefore, becomes necessary that the parts having sliding motion relative to each other, be designed to minimise wear. During rubbing some fundamental changes occur in the surface of the contacting materials and these changes determine the nature of the wear process and friction force. The study of the complex phenomena occurring during rubbing and the need to minimise both energy and material losses in mechanical systems has led to an enlarged interest in the field of Tribology, the science of friction, wear, and lubrication.

Tribology finds applications in all industrial sectors including the aerospace, automotive, engineering, construction, biomedical, textile, optical, cosmetics and microelectronics industries. On average, 30 – 40% of the product cost is related to materials, hence improved materials and related technologies have a very significant impact on the economy. Losses due to wear of materials have been estimated by various sources to 1.3 – 1.6% of the GNP of an industrialized country (Jost, 1966; Czichos & Habig, 1992; Evans, 1977; Molgaard, 1984). Modern materials and related technologies offer adequate solutions to friction and wear problems. Improved tribology will consequently contribute to a better environment, society, and we will be able to provide a cleaner and greener to our future generations to come. Hence, in view of the quantum of the loss due to wear, it becomes imperative for an engineer to develop better defense against wear by exploring newer wear resistant and cost effective materials for the tribological applications.

The necessity to minimize wear has given impetus to the development of the new wear resistant materials and has attracted the attention of the materials scientists worldwide. A lot of research work is going on in the direction of the development and the tribological characterization of lightweight composites based on aluminium or magnesium alloys for the last 50 years. The industries manufacturing the transport systems, be it land, air, or space, are continuing their quest to reduce weight and have a high strength/weight ratio of the components in order to increase the life and efficiency of engineering systems. The aim of the composite development is to attain a spectrum of properties, which cannot otherwise be obtained in any of the constituent materials. A wide variety of composites containing the fibres, whiskers, and ceramic particles have been developed for wear resistant applications. The underlying principle here is to utilize the mutual advantages of both the phases when the less desirable features
of these phases are mitigated by the presence of the second phase. The morphology (i.e., size, shape, distribution, and volume fraction) of the second phase critically controls the mechanical properties of the two phase system which in turn influence its tribological behavior.

The development of composite materials following a wide variety of processing techniques and the design and manufacturing technologies is one of the most important advances witnessed in the history of materials. Composites are multifunctional materials having excellent mechanical and physical properties that can be tailored to meet the service requirements of a particular application. The unusual characteristics of composites equip the engineer with enormous opportunities to design the materials possessing unique properties that are not possible with conventional monolithic materials. Many manufacturing processes for composites have been commercialized for the fabrication of large, complex structures, allowing consolidation of parts, leading to reduced manufacturing costs. The uniqueness and non-conventional nature of composites do incorporate complexities in design, analysis, and fabrication due to their peculiar properties. However, the recent advancements in processing techniques coupled with advanced computational tools and numerical methods are playing a vital role in overcoming such obstacles and aiding in continued growth and application of composites.

Global concern over energy crisis that is being faced world-wide has given impetus to research related to identifying robust solutions to meet the need. Rapid depletion of oil reserves, increasing demand for fuel efficiency and regulations on emission has turned the attention towards light-weight materials. Research on these materials is in focus to achieve multiple-performance reliability, along with easier material processing, machinability/formability and high load-bearing capacity/structural strength. Energy efficiency, recyclability and sustainability are also in the focus. In this context, R&D of light weight composites, especially for weight-critical applications such as in automotive, aviation, sports, electronics and communication sectors (Gupta & Sharon, 2011; Kainer, 2006; Miracle, 2005; Rohatgi, 1996). The increasing use of Al- and Mg-based materials and polymer-based composites in the automotive industry is an excellent example of materials selection, wherein factors, such as material availability, processability, cost, properties, environmental issues, recyclability, fuel efficiency, etc., are all taken into account, together.

Tribology, the science and technology of interacting surfaces in relative motion, is primarily concerned with the friction, wear, and lubrication of moving parts in instruments, machinery, manufacturing, and technology. However, the definition must be improvised by adding that Tribology is the science of friction that aims to save energy, resources (money and materials), environment, resulting in loss minimization and improvement in quality of the product and health of the people. Keeping in view, the recent concerns related to energy, society and environment, it could be said that tribology research is the key towards a sustainable growth of society as it has an influence on our day to day life. As rightly pointed by Olander (2013), the tribology is everywhere every day; the moment you start moving tribology comes into play right from brushing teeth to charging cellphones to drinking yoghurt. Tribological phenomena are associated in every aspect of life automotive, aerospace, cosmetics, human body, and nature. Hence, better tribology practices could result in the conservation of scarce earth resources, higher energy efficiency, prolonged component lifetimes, better environment, society, and thus, helps improving the quality of life.

Tribology research contributes to the modernization of industry, and has strong impact on consumption of resources, namely, energy and materials through the development of better quality products and more efficient production system. It significantly affects the life-cycle and production-cycle issues in all industrial sectors, through the implementation of novel materials and technologies that result in products with improved performance. It is mostly concerned with improving the efficiency and reliability of ma-
chinery, production equipment, and systems for manufacturing. Through the establishment of prolonged life-times and improved production efficiency, it has a major impact on the reduction of raw materials consumption and generation of waste.

Globally, considerable effort has been and is being devoted, to tribology research. Consequently, a vast amount of know-how is available, and some new and exciting developments are still underway. With regard to transport systems in general, tribology research is concerned with improving the efficiency of engines, leading to reduced fuel consumption and reduction of emissions. In the automotive and aircraft industry, the trend towards decreased fuel consumption leads to higher utilization of lightweight materials. Thus, much of the work is concentrated on the tribology of new materials and designs, using surface engineering, improved lubrication methods, and composite materials. More efficient and cleaner production of energy is often critically dependent upon the construction material of power generation plants, and this in turn relies upon the use of adequately performing materials. Reduction of waste is obtained through the longer life-time of components, and the better efficiency of production processes. Advanced surface coatings add physical properties, such as lubricity, hardness, or corrosion resistance, to lower-valued substrates that improve the overall quality of the component. Scarce resources can thus be conserved or toxic materials substituted by application of appropriate coating systems. The reduction of friction in moving elements results in energy savings. Environmentally friendly, bio-degradable lubricants offer great potential to reduce environmental pollution. In particular cases, advanced materials can even avoid the use of lubrication, offering considerable economical savings as well as reduced environmental loading from wasted lubricants. New designs of mechanical systems enable the use of advanced composite materials such as engineering ceramics, coated surfaces, or reduced lubrication consumption in applications, which up until now remained inaccessible for these new technologies. Implants in the human body only function reliably when problems of bio-compatibility, corrosion, and wear have been overcome, and in all these areas tribology has played a crucial role. Hence, it can be seen that tribology has a significant impact on our economy, society and environment.

Energy is the driving force for all human activities. Nowadays, energy is deeply embedded in each of the economic, social, and environmental dimensions of human development. Energy services provide an essential input to economic activity while they improve living conditions and environmental quality. They also contribute to social development through education and public health, and help meet the basic human needs for food and shelter. However, extensive use of energy results in increasing carbon footprints and greenhouse gas emissions whereas mismanagement of energy resources can deteriorate existing ecosystems (Tzanakis, Hadfield, Thomas, Noya, Henshaw, & Austen, 2012).

Recently, a study has highlighted the loss of energy in passenger cars by friction only and suggested the ways to minimize the huge economic losses by utilizing improved tribological practices (Holmberg, Andersson, & Erdemir, 2012). It has been indicated that in passenger cars, one-third of the fuel energy is used to overcome friction in the engine, transmission, tires, and brakes. The direct frictional losses, with braking friction excluded, are 28% of the fuel energy. In total, 21.5% of the fuel energy is used to move the car. Holmberg et al. (2012) further suggested that by taking advantage of new technology for friction reduction in passenger cars, one can reduce the losses due to friction by 18% in the short term (5–10 years) and by 61% in the long term (15–25 years).
ORGANIZATION OF THE BOOK

The book is organized into 13 chapters and includes processing routes and tribological characteristics of composites materials like MMCs, PMCs, and biometrials apart from a chapter on biomimetics. A brief description of each of the chapters follows:

The chapter reviews the various processing/synthesizing routes of Light Metal Matrix Nanocomposites (LMMNCs), their microstructural characteristics, mechanical behaviour, and tribological properties. The authors suggest that the drawback of reduced ductility in micron sized reinforced composites can be overcome with nano-scale reinforcements. The potential of LMMNCs as advanced materials possessing superior strength and ductility along with excellent wear resistance has been emphasized.

Chapter 2 describes the fundamental issues (i.e. materials as well as tribology issues) of the self-lubricating copper matrix composite under dry sliding contact. It is suggested that for fabrication of good metal matrix composites for tribological applications, knowledge from both materials science and tribology is required. The chapter also introduces the tribological aspect of self-lubricating copper matrix composites for tribological applications.

Chapter 3 illustrates the effect of addition of solid lubricants on the high temperature friction and wear behavior of Ni-based composites. The importance of synergetic action of a combination of low and high temperature solid lubricant, nano or micro powders of two or more solid lubricants has been highlighted. A comprehensive review on the fabrication of the Ni-based self-lubricating composites containing graphite and/or MoS2, Ag and/or rare earth, Ag and/or hBN, as solid lubricants and their friction and wear behavior at room and elevated temperatures has been included. The chapter also discusses the tribological behavior of some lubricating electro-deposited nickel-base coating containing graphite, MoS2 or BN and graphene.

Chapter 4 explores the potential of a new class of metal matrix composites reinforced with carbon nano particles for the electrical sliding contact application. The chapter includes reinforcement of nanoparticles and innovative microwave processing technology to fabricate copper-crystalline carbon composites and examines their friction and wear characteristics.

Chapter 5 presents an overview of friction, sliding friction, and contributing factors such as adhesion, ploughing, deformation, third body, time dependence, mechanisms of friction in metallic materials. It also provides an overview of adhesive and abrasive wear and wear mechanism in mild and severe wear regime for metallic materials. Important material properties, environmental effects, and operating parameters have also been highlighted. The importance of Particle Aluminium Matrix Composites (PAMCs) with soft and hard dispersion has also been included and discussed.

Chapter 6 addresses the issues related to the tribocorrosion of metal matrix composites and provides an overview of the current knowledge of the mechanisms involved in the degradation of MMCs due to combination of electrochemical and tribological phenomena and available testing procedures.

Chapter 7 illustrates the importance of composite materials over single phase materials, and further explores the importance of natural fibre reinforced composites over synthetic fibre reinforced composites. The authors present a comprehensive review on tribological characterisation of composite materials and highlight the importance and potential of composites as TRIBO material in engineering systems.

Chapter 8 describes the advantages and disadvantages of several surface modification techniques on orthopedic implants. A critical review on the major tribological and biological outcomes of these modifications is included. Some results of recent investigations carried out by authors have been presented and explained. Futuristic trends in bio-tribological effects of orthopedic implants have been discussed.
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Chapter 9 highlights the importance of surface characteristics such as microstructure, composition, mechanical properties, crystallographic texture, and surface free energy in achieving desired biocompatibility and tribological properties thereby improving the functional performance and in vivo life of artificial articulating implants. An overview on important surface modification techniques, their capabilities, different physical, chemical, mechanical, and biological properties of modified surfaces/implants including implant simulator tests are also presented. The clinical performance of surface modified implants and new surfaces for potential next-generation articulating implant applications is discussed.

Chapter 10 introduces the principles of designing surface texturing based on biological analogues. The chapter specifically relates to bio-mimetic and highlights the importance of deterministic structured textures that allow species to control friction and condition their tribological response for efficient function. The chapter draws a comparison between industrial surfaces and reptilian surfaces. It further highlights the feasibility an engineered surface by laser texturing based on the reptilian ornamentation constructs in controlling the friction. The author suggests that mimicking reptilian surfaces is potentially capable of generating advanced deterministic surface constructs for efficient tribological functions.

Chapter 11 addresses the issues and challenges associated with the conventional drilling of Fiber-Reinforced Plastics (FRPs) and reviews the status of the work reported in the area of conventional drilling of FRPs. A state-of-the-art research review is presented in light of the capability of advanced machining techniques for machining of FRPs. Advanced machining techniques, such as Electric Discharge Machining (EDM), Electrochemical Machining (ECM), laser beam drilling, vibration-assisted drilling, and Ultrasonic Machining (USM) for FRPs has been discussed and the limitations associated with the advanced machining of FRPs have also been highlighted.

Chapter 12 addresses the issues related fragmentation, interfacial adhesion, and strength of polymer-based composite reinforced with natural fibre that have been treated with different concentrations of NaOH and presents an analysis of fragmentation technique using ANSYS.

Chapter 13 gives an overview of Quickstep processing, an Out-Of-Autoclave (OOA) approach, a relatively new technique for manufacturing composites. The basic principle of Quickstep processing and functionality of typical Quickstep plant are also explained. The chapter also includes a survey of different aerospace materials being investigated in Quickstep, the potential of new materials development for this process, the welding technique, in service capabilities of Quickstep cured samples, and journey of Quickstep from patent to commercialization.

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REFERENCES


