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Edited by Chandrasekar Muthukumar, Senthilkumar Krishnasamy, Senthil Muthu Kumar Thiagamani, and Ganesan Chinnachamy

Tribological Properties, Performance, and Applications of Biocomposites

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Preface

Biocomposites are touted as a promising substitute to conventional composites in various applications due to their biodegradable characteristics, low density, and moderate mechanical properties. As these materials are intended for applications in the automotive, aerospace, biomedical industries, etc., it is essential to explore their tribological behavior.

The chapters in this book cover a broad range of topics, including the tribological properties of biocomposite based on thermoset and thermoplastic resins, the influence of fiber pretreatment techniques, and nanofillers for the enhanced tribological performance. In addition to this, the characterization methods employed to assess wear and friction characteristics of the biocomposites were discussed.

This book aims to provide researchers, engineers, and students with a comprehensive knowledge of tribology in the context of fundamental principles, experimental techniques, and practical applications. This book will serve as a valuable resource to understand the factors influencing the tribological performance of the biocomposite materials and their suitability for various applications. We sincerely hope that this book will inspire further research and innovation in the field of tribology and can unlock the full potential of biocomposites.

The contributors to this book are distinguished researchers and experts in the field of tribology and biocomposites. Their collective expertise enables us to gain deeper insights into the tribological behavior of biocomposites, making this book a valuable reference for both academia and industry. So, we express our sincere appreciation to the contributors.

1
Tribological Characterization of Biocomposites: An Overview

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1.1 Introduction

The desire for environmentally acceptable materials fueled the establishment of a slew of pollution control laws, and the engineering imperative for cost-effectiveness in all areas pushed us to seek low-cost alternatives. Fossil-emerged sources are limited; hence, researchers and experts are now looking for alternative sources of conventional sources. Green technology, housing, solutions, energy, lifestyle, and materials are all part of the green environment [1, 2]. Natural fiber polymer composites (NFPCs) are a versatile material with a wide range of applications due to their capabilities and unique characteristics. Sisal, coconut coir, jute, *Calotropis gigantea*, kenaf, palm, banana, bamboo, bagasse, flax, and hemp are among the most often used natural fibers. Natural fibers provide several advantages, including low price, low mass per volume, minimal energy inputs, and superior mechanical qualities [3, 4]. Plant fibers, on the other hand, have some limitations. They can absorb moisture from the environment, resulting in a weak connection between the resin and the reinforcement. To overcome these conditions, fibers require some chemical treatment to modify their surfaces [5]. NFPCs are used for a wide range of engineering applications, like structural/nonstructural and tribological applications, because of their significant qualities. Biocomposites are used in the automobile industry to produce different parts like window linings, bike mudguard headliners, package trays, cupboards, and other vehicle internal spare parts. Other applications such as sliding panels, linkage, bearings, and bushings are fast-growing. Bio-composites are occasionally subjected to a variety of tribological loading environments, exposing the component to various forms of wear mechanisms such as adhesive, erosion, corrosion wear, and two-and three-body abrasive sliding wear. To improve the usefulness of composites in various technical sectors, it is essential to examine and investigate their tribological performance [6].

1.2 Tribological Characterization

The term “tribology” derives from the Greek word tribos, which means “rubbing.” Tribology is the study of lubrication, wear, and friction between surfaces in relative motion. Friction is the force that prevents two bodies from moving in the same direction. The friction coefficient is the proportion of the frictional force to the perpendicular force acting on the outer layer. The sources of tribological effects are presented in Figure 1.1 [7].

It is a dimensionless number that indicates how much friction exists between two surfaces. Tribometers are devices that are used to measure the friction coefficient. The friction coefficient is independent of the contact area and sliding speed and is determined by the surface roughness and nature of the material. When two surfaces come into contact, they wear away at each other, removing material. Adhesive wear, abrasive wear, surface fatigue wear, and corrosive wear are the four types of wear that can occur as a result of friction. When two adjacent surfaces slide against each other, adhesive wear occurs. Large values of friction coefficients occur from adhesion wear. Abrasive wear is the wear that occurs when a rough surface moves over a soft surface [7].

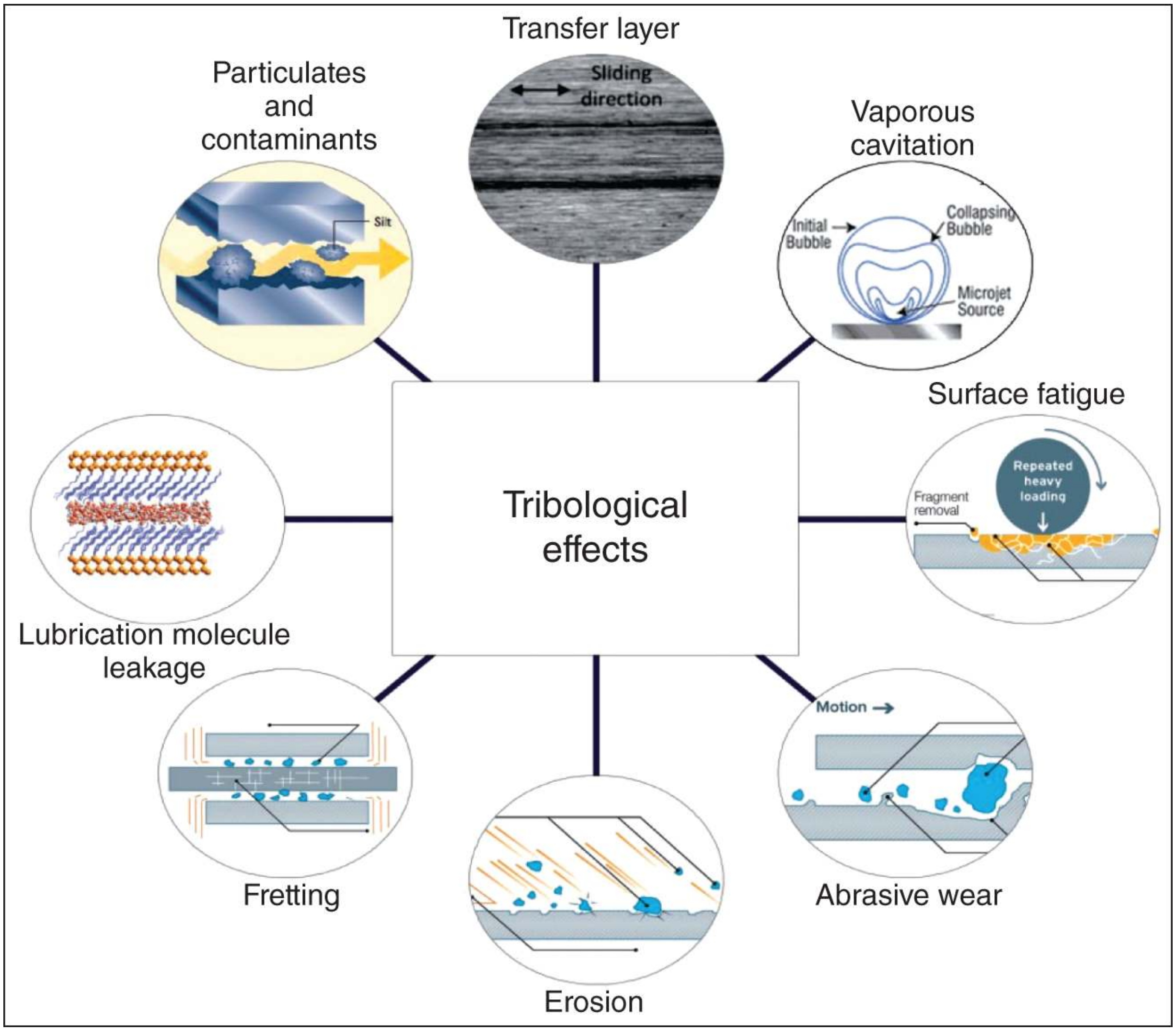

Figure 1.1 Various sources of tribological effects.

Source: Karthikeyan et al. [7]/with permission of Sage Publications, Inc.

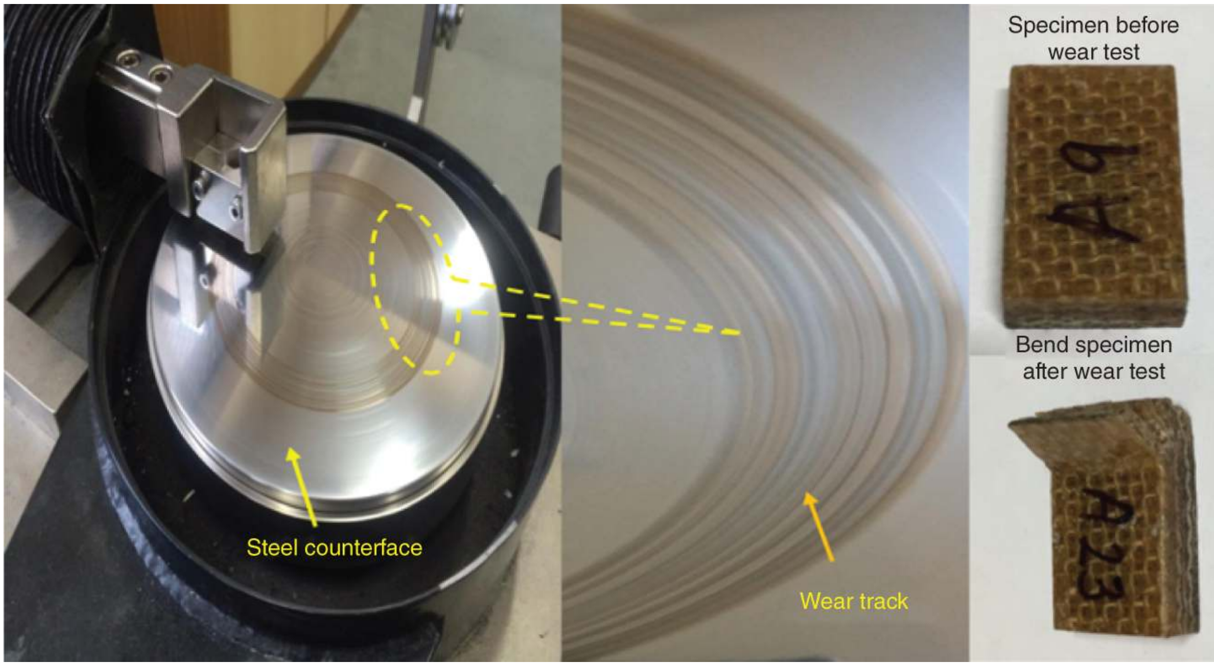

Figure 1.2 Wear experiment for jute/hemp/sisal epoxy laminates.

Source: Chaudhary et al. [6]/with permission of Springer Nature.

1.2.1 Flax Reinforcement

The tribological performance of low-cost and regionally available jute/hemp/flax fibers was checked by using the hand-layup method. The tribological performance of the novel bio-composites was evaluated in terms of frictional characteristics and sliding wear in dry contact, employing a range of process parameters such as applied load, sliding speed, and sliding distance. Natural fibers with epoxy polymer improved the wear resistance rate, and the effect of speed is insignificant on the coefficient of friction (CoF) at higher speeds [6]. Natural fibers (jute, hemp, and flax) combined with epoxy polymers improved the tribological performance of all the laminates studied. At higher speeds, the effect of speed on CoF is minimal, while the impact of applied load on CoF is insignificant. Each form of specimen has a distinct average CoF. As a result, the friction conditions on the created composites are influenced by the type of natural fiber used. Epoxy's wear performance has been significantly improved by using various combinations of natural fibers as reinforcement. Sliding speed, in addition to the applied stresses, has a significant influence on the wear performance of the composites generated [6, 7]. Wear experimental setup is depicted in Figure 1.2 [6].

An investigation has been made on the friction and tribo properties of natural fiber 3D braided yarn polylactic acid (PLA) composites with woven fabric reinforcement exposed to dry sliding. For various weights and sliding velocities, the impact of different fiber weight fractions is examined. The natural-fiber-reinforced PLA composites are found to have a high CoF and wear rate. The addition of natural fiber braided yarn to PLA, aliphatic polyester, increases the frictional force and decreases the composite specimen height loss. With increasing normal loads, the wear rate and specific wear rate of pure PLA and natural fiber/PLA composites increase. The specific wear rate of PLA is reduced by roughly 95% when natural fiber reinforcement is used at 35 wt% [8].

1.2.2 Coconut Coir Reinforcement

Coir, obtained from the fibrous middle layer of coconut fruits, is a hard and stiff biodegradable lignocellulosic fiber. It has a high lignin content that makes it weather resistant and strong, and it can be chemically modified [9]. It is found that coir fibers, when chemically treated, improve their interfacial interaction with PLA resin and are thermally stable up to 265 °C. Coir-fiber-reinforced polyester laminates were made and evaluated for wear and frictional behavior using a block-on-disc (BOD) machine. The worn-out surfaces are examined by scanning electron microscopy (SEM). By adjusting the applied stresses, the particular wear rate and friction coefficient are investigated as a function of sliding distance. It is found that the composites have better wear performance than the neat polyester. SEM observation showed that there was no pull-out, tear, or breakage of fibers, but there was deformation and micro-plowing in the resinous regions [10].

1.2.3 Banana Reinforcement

Banana fibers, known as Musa fiber, are extracted from the outermost layer of the banana trees by the retting process, which improves the quality of the fiber. Banana-reinforced epoxy composites were fabricated by hand-layup, and their mechanical and tribological behavior was tested at different orientations using a pin-on-disc tribometer. It is found that at 0°, the wear rate is less than at 90°, as the fiber area is at its maximum at 90° orientation [11].

It is observed in the tribological behavior of banana/coir composites reinforced with glass fibers that were made using a compression molding procedure. The fibers are silane treated, and the composites' wear resistance is tested on a pin-on-disc tribometer by altering the force on the pin, disc speed, and fiber weight percentage. According to the wear characterization performed using SEM, the dry body abrasive wear test demonstrated that integrating natural fiber with synthetic fibers enhances the wear resistance capability and increases the wear life of the composites. According to Taguchi's design of experiments and analysis of variance methods, the most influencing factor is the type of composite fiber (96.11%), followed by the speed of disc rotation (1.85%), and the load on the pin (1.85%) [12].

1.2.4 Hemp Reinforcement

Hemp fiber is extracted from the stem of the plant by various processing techniques such as retting,

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