"TRIBO": a Retrospective Perspective

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“TRIBO”: a retrospective perspective

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Abstract. Adhesion, lubrication, and wear at tribological interface *in situ* balance energy loss of biological and biomimicry contacts. The friction coefficient ~0.01 or less for amphiphilic tribos such as joint articulation and ocular tribology have promoted research for innovation of nature inspired materials. Bio-tribology is an emerging domain for researchers, scientists, manufacturer, and nature inspired material designers in amalgamation of biochemistry, materials science, mechanics, technology, and economy. The author is inspired by heterogeneity in expressing fundamental expression of tribology in consideration of fluid-mosaic membrane, supramolecular non-covalent attraction, hydration lubrication, biomechanical diffusion, and deviation of classical friction law.

Keywords: Socioeconomic, Energy balance, Supramolecular interactions.

1 Introduction

Nature is designing surfaces, interfaces, and interphases across millions of years for balancing environmental third-body reactions under a conscious umbrella of the biosphere in prediction of non-fundamental friction force [1]. The bullock cart was preferred during ancient times for transportation of materials at rolling, sliding, and stick-slip contacts. The first heavy locomotion initiated on April 16, 1853, for public transport in India at sliding and rolling mechanical contacts originally based on coal-steam-based external combustion engines. The second half of the 20th century has initiated the manufacturing of petroleum fuel-based internal combustion engines or economical light vehicles as a source of personal transport in urban cities for reducing human energetics, enhancement of oxidative stress in the anthropogenic environment, and a work-life imbalance due to transformation of mechanical work by machines as per the requirements of the global economy. The heavy dissipation loss of fuel energy over land in transport sector, biodiversity loss in construction of roads, and relatively fast transport requirement had steadily channelized a materials-energy balance for transforming carbon footprints [2-3]. The mankind has transformed material science from the ‘Stone Age', ‘Bronze Age’, and the ‘Iron Age’ in designing defensive mechanical tools or materials handling devices to virtual realities and fourth generation industry at tribological contacts [4-5]. The SARS-CoV-2 pandemic is an implicit load over bio-tribological contacts due to CO_2 anthropogenic loading, lowering requisite mechanical work by human energetics, and transformation towards virtual realities for strengthening socioeconomic frontier. The diverse and inclusive domain of nanotechnology from molecular adhesion or nanotribology have been encouraged by academic fraternity for last six decades. The energy generation, utilization, and economy for development of science and technology have evolved global political goals for reducing carbon footprints.

2 Tribology

The word "TRIBO" borrowed from Greek etymology pertaining to "RUB" and the suffix "-LOGY" stands for "INVESTIGATION" complete the word "TRIBOLOGY" now an interdisciplinary scientific or academic domain. The word tribology is coined by a committee of the British Department (Ministry) of Education and Science on March 9, 1966 in writing a report of the economy of friction, wear, and corrosion for industry needs [6-7]. The industrial revolution, paradigm shift, and socioeconomic indicators for the fruitful impact of 21st century tribology are expedited in the scientific spectrum [8]. The similarity of adhesion, lubrication, friction, and wear at biological tribological contacts due to existence of lubrication regimes have promoted "Biotribology" shortly afterwards 1970 with a significant contribution in a broad field of study for last "Fifty" years [9]. The bio-tribology is a science at the biological surface, seismic stick-slip plane, natural phenomenon, biomaterials, human locomotion, and personal care [10]. The fuel-energy expenditure for safeguarding a minimum mechanical work is viable for balancing net mechanical efficiency at the bio-tribology interface. The biomedical accreditation of biodegradable polymers has promoted bio-tribology for the achievement of human performance indicators, biomaterial manufacturing, policy, technology, biomedical surgery, and the economy for last five decades as shown (Fig. 1) for fundamental academic expression. The promotion of sustainability is a projected socioeconomic and political agenda for reducing fuel energy expenditure, decent work for economic growth, and privacy policy for integrity of cyber security, and transformation of mechanical contact energy losses by clean energy driven vehicles. The digital revolution, internet of things, artificial intelligence, virtual realities have encouraged for smart energy generation based on triboelectric nanogenerators and storage in reducing conventional fossil fuel oriented electricity generation as per the global requirement.

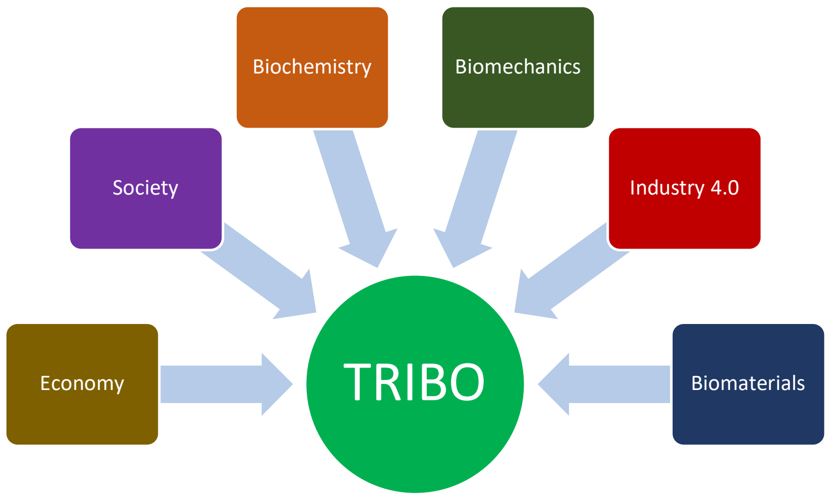

Fig. 1 The reinforced indicators of bio-tribology in included academic expression

3 Friction, Adsorption, and Wear

'*Friction*' is a resistance evolved at interfaces having relative motions or at rest such as mechanical systems, biological systems or membranes, and natural phenomenon. The protection of life and personal liberty at 'Biotribology' interface is invincible under environmental reaction for a synergistic human kinematics by synovial lubrication on articular cartilage, ocular tribology, soft tribology, vascular friction, and stick-slip tactile friction. The classical friction law dated back to 1699 preferred in designing of conventional mechanical surfaces states that the friction force to proportional to normal reaction, and the friction force is independent of nominal or apparent contact area [11]. The classical friction law is expressed for rendering of tribological applications.

$$F = \mu N \tag{i}$$

Where, F is friction force, N stands for normal reaction, μ is friction coefficient assumed to be null in ultra-vacuum, dependent on environment, and approximately unity for mechanical interlocking asperities dry contacts of stick-slip friction. The real area of contact is evolved for prediction of frictional properties for soft materials with normal loading proportionality, decreasing function of shearing, slowly increases at rest through aging or reducing surface tension and drops at slip inception [12]. The adsorption of biomacromolecules influence friction and wear of synovial lubrication under bio-lubricants scarcity, aging, diversity, and work-life balance due to mechanical loadings. The biomechanical, anatomical, physiological factors have been included in an academic survey of methodology for determination of friction coefficient of natural systems with biomedical intervention [13]. The friction force is a strong function of velocity in phenomenon of seismology, high speed lubricated bearings or stribeck curve, aerodynamic drag of space machinery, articular cartilage, and ocular tribology. The contact mechanics, friction, wear of materials are the fundamental pillars for safe and energy saving designs [14]. The correlation of wear, adsorption of environmental third bodies, and friction have been observed for biological or bio-inspired surfaces conversely "Null" in ultra-vacuum in absence of environmental reactions.

4 Surfaces, Interfaces, and Interphases

The scientific modification of tribological surfaces, interfaces, and interphases is an alternative way for innovation of materials-energy balance. The superhydrophobic and superoleophobic properties found over biosphere have academic potential to biomimicry tribological contacts for synchronization of surface energy, surface tension, and friction coefficient [15]. The thin film coatings, surface science, physical vapor deposition, and surface modification have been altering properties such as abrasion resistance, corrosion resistance, wear resistance, protection from environmental erosion, ductility, and viscoelastic rheology for mechanical or biomedical applications. The design and applications of superomniphobic surfaces have evolved academic or economic interests due to self-cleaning and low surface energy characteristics [16]. The solid-fluid interaction, thermal loading, and transformation of CO_2 into solid matter in the form of natural fibre composites have been transforming magnum energy into mass due to conscious umbrella of "*Nature*" [17]. The rule of mixture binds mechanical properties of anisotropic and inhomogeneous natural fibre composites having hydrophilic cellulose biopolymers, hydrophobic lignin, and residual mechanical interlocked molecules for providing perfect physiochemical bonding [18]. The heterogeneity of third bodies over tribological interface regulates mechanical performance in addition to materials characteristics, state variables, and economic viability [19]. The nanotechnology has been emerged for last six decades in modulation of molecular research, macromolecular structure, and biofunctionalization in a conscious umbrella of nature [20-22]. The interlinking of hydrophobic units with hydrophilic units by heterogeneous molecules evolves a nature inspired macrostructure in designing surfaces, interfaces, and interphases.

5 Biomechanics

The classical mechanics, equilibrium of forces and moments, action-reaction hypothesis have been viable for assessment of membrane tension under quasi-static biomechanical loadings. The biomechanical factors influence adhesion, lubrication, and frictional characteristics of amphiphilic biological membrane in mimicry synthetic polymer membranes [23-25]. The biomechanical diffusion, biological properties, membrane tension, and fluid properties exhibit a boundary lubrication coating in exploring ultra-low friction coefficient of amphiphilic membrane [26]. The surface compression of bio-membrane due to unforeseen biomedical grounds is lean biomechanics for transformation at materials-energy balance. The evolution of surface chemistry at surfaces, interfaces, and interphases defines a boundary for rationalization of energy dissipation losses between materials and surrounding environment [27]. The ultra-low friction coefficient of ocular tribology is anticipated from hydration lubrication of soft matter [28]. The lubricin is a boundary lubricant for coating superficial zone of articular cartilage in providing ultra-low friction coefficient, scarcity a reason of moderately risk domain for perceptible friction, and HA for hydrodynamic lubrication under dynamic locomotion [29]. The effective synovial lubrication of soft interfacial materials provides durability up to 100 years for healthy articulation however morphological transformation, aging, and environmental severity lead to significant pain or loss of quality of life [30]. The materials and energy balances of synchronized fuel oxidation implicit relationship have been fundamentally included for rationalization of tribology surface, interface, and interphases [31]. The energy dissipation mechanism of soft hydrogels is dependent on exudation, viscoelastic properties, permeability, and hydrophobic association for providing low friction coefficient in bio-tribology applications such as ocular tribology or articular cartilage [32]. The biotribology is influenced by supramolecular chemistry in regulation of frictional boundary, energy optimization, and biomechanical indicators.

Conclusions

The industry evolution of transport and energy sector, economic parameters, ecology, and materials-energy balance have enunciated scientific research at biomimicry surface for minimization of friction drag. The friction coefficient of amphiphilic membrane is influenced by permeability, biomechanical loading, aging, and environmental factors. Supramolecular biochemistry at tribological interface is due to membrane thermodynamics, hydration lubrication, and interlinking of hydrophilic polar head with hydrophobic non-polar tail for synergy of heterogeneous fluid-biomolecules system. The biomaterials industry is a billion dollars fast growing market of metals, ceramics, synthetic polymers, and natural materials preferred in biomedical applications.

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Author prepared a personal viewpoint as per the requirement for achievement of performance indicators. Author is inspired by heterogeneity for a diverse and inclusive content, rendering, viability, and academic integrity.

Ethics declaration

Author has prepared a personal viewpoint without involvement of human subjects, living surface, and clinical investigate inherently an academic expression for fundamental structuring of retrospective biomechanical domain

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