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Heterogeneous Rubbing Surfaces, Interfaces, and Interphases

Pankaj Tomar

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Pankaj TOMAR[1,2]

[1]IGDTUW, Kashmere Gate, Delhi, India
[2]GGSIPU, Dwarka, New Delhi, India
e-mail ID; pankaj_12343@rediffmail.com

Abstract

Soft matter at rubbing contacts is promoted by researchers during 21st century for advancement of technology and promotion of materials and energy balance. Diversity of biology is transforming mechanical energy for millions of years of life as a function of heterogeneity, textured surfaces in defeating environmental reactions, and body kinematics. Strong van der walls forces are invincible for explaining mechanics and mechanisms of Geckos toe attachments or detachments.

Keywords: Friction, Lubrication, Adhesion, Kinematics, Anisotropy

1. Introduction

Bio and bio-inspired tribology is a science domain to investigate surface properties borrowed from diversity of biology for designing engineered surfaces for rationalization of environmental friction [1-2]. The dolphins and larger aquatic vertebrates can move with surprisingly high locomotion speeds and the drag power experienced in normal rectilinear motion in assuming rigid body motion have proportionality ($F_d \propto V^2$) with a square of the locomotion speeds [3-4]. The turbulent skin-friction drag on slender bodies of revolution has additional interest for experimental investigations without boundary layer separation to rationalize the friction drag, noise of air, and hydrodynamic hulls borrowed from an unseparated flow pattern of the turbulent drag of a dolphin presented by Gray's in 1936 on aquatic animals [5-6]. The slippery mucus naturally secreted by fish skin is important to protect the diversity of biology against predator attack, allowing it to swim faster, and remain underlying for explaining the mechanism of ultra-low friction coefficient [7]. Surfaces, interfaces, and interphases have been preferred for heterogeneity in regulating tribological boundaries as surface chemistry as environment for tribological performance in engineering applications.

The emperor penguins provide excellent underwater locomotion in nullifying the influence of gravity in horizontal swimming due to air lubrication or reducing frictional drag, buoyancy

forces alone cannot explain the penguin's speeds, and cavitation plays no part in bubble formation [8]. The simulated lotus leaves, shark skin, coral tentacles, whale skin, dolphin skin, and other biology structures promote for the development of antifouling technologies in marine applications [9]. The underlying mechanisms of the self-cleaning behavior of liquids on functional surfaces is an emerging research topic for the non-stick household commodity sector, designing of superhydrophobic surfaces, and for applications of bio-inspired science [10-11]. The super-hydrophobicity is preferred to the biofouling prevention in two orientations; designing a surface that repels biological entities; designing a surface that minimizes the water wetted in water by keeping an air film between the water and the surface so that biological entities encountering the solid surface with a low probability [12]. The bio-inspired non-stick tribology is additionally reinforced in alignment with socioeconomic and materials-energy balance.

2. Bio-inspired tribology

The surfaces, interfaces, and interphases provide a boundary at rubbing contacts for optimization of energy dissipation due to change of state variables/materials viable for reduction of environmental reactions [13]. The surface ice accretion is an economic goal in the energy and transportation industries due to the requirement of condition monitoring than conventional de-icing approaches involving the use of mechanical, electrical, chemical, or a combinatorial approach inspired by nature [14]. The superhydrophobic and superoleophobic properties found in nature are useful to benefit various potential applications and bionic properties as nature for millennia evolved plants, insects, and animals in water-repellent or low surface tension liquids [15-21]. Super wettability is pertaining to the understanding of the underlying mechanisms of wetting phenomena in nature including applications inversely to self-cleaning mechanism of lotus leaves [22]. Green tribology is related to the environmentally friendly design and manufacturing of mechanical surfaces for advancement of sustainability at the forefront of scientific innovation from bio-inspired engineering [23-25].

The boundary lubricant (PRG4/Lubricin/SZP) at articular cartilage bind and regulate ultra-low friction coefficient during locomotion due the few layers of boundary coat over soft matter in addition to the biomolecules heterogeneity for providing interface [26-28]. Human skin is amphiphilic substrate providing sticking and slipping interface for defeating environmental reactions, mechanical loadings evolved at "tribo" interface of personal protective equipment/face masks, providing the artificial oil lubrication for reducing environmental harm [29-32]. The attachment and detachment of Geckos toe is assumed a superb designing of nature

for extraordinary climbing against gravity on hydrophobic/hydrophilic/rough/smooth/wet surfaces in large due to the presence of transient van der Walls forces [33-35]. Nature is evolving surfaces and heterogeneous materials from billion years from nanodomain to macrodomain for interplaying between morphology, physiochemical properties, and functionalization of bio-inspired engineering (Table 1).

Synergy	*Keywords*
The involvement of kinematics of aquatic animals in locomotion for prediction of thrust power, drag force, and muscle power during mechanical work in environment of water molecules	**Gray's Paradox**
Biological substrates with an aqueous environment provide low friction drag in the locomotion of diversity of biology for reduction of drag force such as catfish mucus secure friction coefficient smaller than 0.005 under tribological boundaries	**Heterogeneity**
Emperor penguins provide excellent water propulsion against gravity by decreasing skin drag due to air lubrication for increasing mechanical efficiency	**Air lubrication**
Natural surfaces found in nature provide apparent contact angle of water more than 150^0 for designing and manufacturing of self-cleaning surfaces and minimization of energy losses at rubbing engineered contacts	**Superhydrophobicity**
Protein, phospholipids, cholesterol, carbohydrates, and hydration shells binds and regulate fluidity of biological membrane under mechanical loadings for providing hydration lubrication	**Amphiphilic membrane**
Superhydrophilicity of cotton or cellulose biopolymer for absorbing water molecules provide faster degradation of materials in socioeconomic rendering e.g., textile industry, medical, and household applications	**Superhydrophilicity**
Superficial zone protein (SZP) 345 kDa provide excellent fluidity over articulating cartilage for preventing adsorption in providing	**SZP**

ultra-low friction coefficient ~0.001 due to boundary lubrication or few layers of molecular coatings/nanocoating	
Surface texturing of human skin covering up to 2 m^2 apparent area of contact with external environment in providing sticking and slipping interface during assessment of friction coefficient reaching approx. "Unity" or more under starved conditions	**Stick-slip skin**
Ultra-adhesion of Gecko setae for preventing slipping in providing perfect sticking during locomotion on roof and vertical walls due to van der Walls forces explaining the mechanism of transient forces or attachment/detachment of biological substrate with surface of locomotion	**Gecko setae**

Table 1 The surfaces of nature such as amphiphilic, oleophobic, hydrophobic, hydrophilic have been observed at tribological surfaces and interphases of biodiversity quoted in brief for biomimicry interfaces included by virtual survey of heading

3. Conclusions

Nature consciousness is an inherent phenomenon for prediction of environmental reaction ahead of covid#19 pandemic in India for modulation to bio-inspired science with academic, scientific, and technological views of author quoted in brief;

- Bio-inspired engineering for rationalization of energy dissipation in reducing environmental drag by changing surface energy and surface tension
- Superhydrophobicity of "Lotus effect" in explaining self-cleaning mechanism of biologically inspired science of fluorocarbons surface mechanisms
- Tactile friction and electroadhesion is visible in daily life for advancement of virtual activities during 21st century in India such as Android phones, Smart shopping, and household electronic devices
- PTFE with low surface energy and surface tension preferred in non-stick cookware as per the requirement of Socioeconomy from tribology domain
- Ideal surfaces surface tension, real asperities contact, and inclusion of vapour pockets beneath liquid in asperities micro reservoirs have been preferred using Young's equation, Wenzel state, and Cassie-Baster surface science models

Author Contribution

Author wrote paper by inclusion of a few author preprints

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Conflict of Interests

None conflict of interests to declare

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