Chapter 9
Potential of Bio-Inspiration in 3- and 4-D Printing

ABSTRACT

This chapter explores the potential of bio-inspiration in 3- and 4-D printing. The authors argue that the true potential of texturing hasn't been realized yet not because of the lack of enabling texturing technologies but because of the severe lack of detailed information about the functional details of texturing in a tribological situation, that is, how surface features, their geometry, interact with the functional gradients present within the subsurface layers to control the friction profile of a structure. The material emphasizes the potential of bio-inspired surfaces in providing a pathway for realizing true synchronization of function through a layer-by-layer customization of surface and subsurface material. In particular the chapter discusses methodologies to extract design parameters that lead to manifesting 4-D printed tribological constructs where surface and sub-surfaces respond optimally to external stimulants represented by the operation conditions of load, speed, and ambient temperature. Successful design of functional deterministic surfaces is not a product of mere biomimicry. Rather, it culminates probing the geometry, texture, form, and construction of the bio-analogue and linking these ingredients to the desired functional profile of the surface in the human engineering domain, that is, generation of bio-inspired functional surface designs stems from implementing design rules rather than replication of natural constructions. Deduction of design rules requires decoding the metrological features and the analysis of surface performance, of bio-analogues using standardized engineering

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methods. Success in designing a bio-inspired surface, therefore, requires a trans-disciplinary approach that combines engineering, physics, and biology. These don't combine naturally since they entail different methodologies of problem solving and investigations. It is hoped that this book would bridge the gap between the disciplines in the context of biomimetic surface design and construction. Further, it is hoped that the material would equip the reader with the basic skills needed to navigate between the biological and the engineering domains.

INTRODUCTION

Tribological surfaces are multi-functional entities that exchange, channel, and respond to external operation parameters of all sorts. They also respond to internal changes of system structure as triggered by any change in environmental operational conditions (i.e. any change in load, speed, ambient temperature, or chemical components). Surfaces also play an important role in protecting the layers of system components from detrimental thermal, chemical, and mechanical effects. The multi-aspect role of surfaces is, therefore, critical in maintaining and advancing the structural, as well as, the functional health of a tribological system.

The role of the surface in preserving a rubbing system is further advanced through energy exchange between the contacts interface and the mechanically affected layers of the rubbing components. Efficiency of that exchange has been recognized lately as a direct, and crucial, contributor to preserving the structural integrity of rubbing components (Kuhlmann-Wilsdorf, 1987, Barber, 1970, Blok, 1970, Ling, 1969, Archard and Rowntree 1988). Further efficiency of energy exchange is deemed essential to reducing the energy consumed in combating friction-induced energy losses and efficiency of motion in general (Ye and Komvopoulos, 2003)., Lai, and Cheng, 1985, Tian and Kennedy, 1993, Deolalikar, et al., 2008, Lal and Mathur, 2007). As a result, modern design paradigms for tribo-systems emphasize customization of textural features of rubbing surfaces. Customization, in general, entails detailed consideration of shape and pattern of individual surface topography components. It also comprises integration of sensory elements within the structure layer of the subsurface to signal the state of the structure. Modern view of surfaces, therefore, have evolved from a "boundary" view to an