Chapter 10
The Structure of Ventral Scale Textures in Snakes in Comparison to Texturing of Deterministic Tribological Surfaces

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ABSTRACT

This chapter introduces the principles of bio-inspired design texturing of surfaces. Texturing is a leading technology applied to modify surface topography. To date, a standardized procedure to generate deterministic textures is non-existent. In nature, there are many examples of deterministic textures that allow species to condition tribological response for efficient function. This work compares industrial surfaces and the structural makeup of ventral scales in snakes. The authors compare the metrological features of the ventral scales to performance indicators of industrial surfaces. It is shown that the metrological features, key to efficient function of a rubbing deterministic surface, are already optimized in reptilian skin. Further, it is shown that this optimization originates from synchronizing surface form, texture, and topology. Results indicate that mimicking reptilian surfaces is potentially capable of generating advanced deterministic surface constructs of efficient tribological function.

1. INTRODUCTION

Surface topography has a crucial influence on friction-induced losses during rubbing of complying solids. Topography affects the mechanics of contact at the interface and influences the quality of lubrication. Therefore, currently, many efforts address the possibility of engineering topographies in order to improve the quality of surface-interaction in rubbing assemblies. The Friction-Induced Energy Losses, FIEL, of a rubbing system has two contributions. The first is a result of friction between the micro-topography at the interface between the contacting bodies. The

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second is a consequence of the friction between the lubricants, if present, with the interface. The magnitude of the second component increases upon using a lubricant with high viscosity (which is necessary to support high frictional loads). Engineering of a rubbing interface aims to reduce the friction between the rubbing bodies. Reduction of the frictional tractions allows using lubricants of lower viscosities and thereby it reduces the losses due to lubricant friction. Successful engineering of surface topography, therefore, leads to reduction in the overall FIEL.

Ideally, the target is to engineer surfaces that yield predetermined rubbing response, and are, in the same time, capable of self-adapting such response in accordance with changes in sliding conditions. Such surfaces, termed as "deterministic surfaces" comprise artificial textures embossed on the rubbing interface. The texture building block is a micron-sized 3-Dimensional geometrical shape (cone, hemisphere, rounded apex, chevron etc.,) which repeats in an array over the desired area of the surface.

There are several techniques to emboss these textures (e.g., multistep honing, helical-slide honing, controlled thin layer deposition (Priest & Taylor, 2000; Willis, 1986; Bolander & Sadeghi, 2007; Santochi & Vignale, 1982), and laser texturing (Dumitru, Romano, Weber, Etsion, Kligerman & Halperin, 1999; Etsion, & Halperin, 2002; Ryk, Kligerman, & Etsion, 2002; Ronen, Etsion, & Kligerman, 2001). The goal of texturing is to create an array of micro-channels and plateaus on the target surface. The plateaus provide raised cushions (islands) for the counter face surface to slide on, and in the meantime, they reduce the contact area between the siding solids. This results in reducing the friction forces between the sliding bodies. The micro-channels aid in reducing oil consumption in lubricated friction by keeping remnants of the lubricant to replenish the interface continuously. Controlling the precision of surface texture generation is currently a pressing problem. This is due to the difficulties multitude of parameters that influence conventional texturing technologies (around four hundred parameters involved in texturing by honing (Santochi & Vignale, 1982). To date, there is no agreement on the optimal topology that textured surfaces should acquire. Among currently available texturing technologies, texturing by means of a laser beam is the most advanced; and is considered by many as a promising enabling technology (Golloch, Merker, Kessen. & Brinkman, 2004; Dumitru et al., 1999; Hu & Ding 2012; Borghi, Gualtieri, Marcchetto, Moretti, & Valeri, 2008).

Laser texturing (LT), as a technology, was available since the seventies of the twentieth century. It's application to frictional surfaces however, began early this century when it was initially applied to mechanical seals (Etsion et. al, 1999; Etsion & Halperin, 2002) then extended to piston rings and cylinder bores (Ryk et al., 2002; Ronen et. al., 2001). The process involves creation of an array of micro-dimples on the target surface using a material ablation process with a pulsating laser beam. The "dimple" acts as a "plateau" and the channel between two dimples acts as a "groove". The grooves retain remnants of the lubrication oil during sliding and thereby they can replenish the lubrication film in subsequent sliding cycles. The plateaux, meanwhile, provide raised cushions (islands), for the surface to slide on, so that the area of friction reduces without sacrificing the load carrying capacity.

Theoretical analysis identified several dimensional groups that influence the tribological performance of a textured surface (Brizmer & Kligerman, 2012; Eichstät, Romer, & Huisin't Veld, 2011; Kovalchenko, Oyelayo, Erdemir, Fenske, & Etsion, 2005; Liu, Han, Xue, & Li, 2010; Mann & Zum Gahr, 2012; Marian et al., 2011; Podgornik et al., 2012; Scaraggi, 2012; Scaraggi, Mezzapesa, Carbone, Ancona, & Tricarico, 2013;Vilhena, Podgornik, Vzintin, & Mozina, 2011; Yin, Li, Fu, & Yun, 2012; Zhan & Yang; 2012). To date,