Chapter 9

The Special Case of Legless Reptiles

ABSTRACT

In this chapter, we draw a comparison between industrial surfaces and reptilian surfaces. We chose the python regius species as a bio-analogue with a deterministic surface. We first study the structural make up of the ventral scales of the snake (both construction and metrology). We further compare the metrological features of the ventral scales to experimentally recommended performance indicators of industrial surfaces extracted from open literature. The results indicate the feasibility of engineering a Laser Textured Surface based on the reptilian ornamentation constructs. It is shown that the metrological features, key to efficient function of a rubbing deterministic surface, are already optimized in the reptile. We further show that optimization in reptilian surfaces is based on synchronizing surface form, textures and aspects to condition the frictional response. Mimicking reptilian surfaces, we argue, form a design methodology capable of generating advanced surface constructs suitable for AM-methodologies.

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 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

DOI: 10.4018/978-1-6684-5638-5.ch009

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 and Taylor, 2000; Willis, 1986; Bolander and Sadeghi, 2007; Santochi and Vignale, 1982), and laser texturing (Etsion et. al, 1999; Etsion and Halperin, 2002; Ryk et. al; 2002; Ronen e. al, 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 and 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, et al., 2004; Dumitru et al., 2004 Hiroki et al., 2011;Hu and Ding 2012Borghi, et al., 2008; Qiu, and Khonsari, 2011).*

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 and Halperin, 2002) then extended to piston rings and cylinder bores *(Ryk et. al; 2002; Ronen e. 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 and Kligerman; 2012, Eichstät, et al., J., 2011;Kovalchenko et al., 2005;Liu, et al., 2010;Mann and Zum Gahr, 2012;Marian, et. al., 2011;Podgornik, et al., 2012;Scaraggi, 2012;Scaraggi et al., 2013;Vilhena, et al., 2011;Yin, et al., 2012;Zhan and Yang; 2012).* To date, however, there is no agreement on the optimal values to be implemented given a particular surface. More importantly, a well-defined methodology for the generation of textures for optimized surface designs is virtually non-existent. Such a process is still viewed as "black art" mainly because of the absence of universal standards that rate design and manufacturability from a targeted-performance perspective. That is, the absence of a holistic surface-design methodology that merges function, form and topography to achieve lean performance within a wide range of contact conditions. Such an approach, while in essence, has not matured as of yet within the realm of human surface engineering is advanced in natural designs especially within the scaled reptiles (squamata). Squamate Reptiles present diverse examples where surface structure, texturing, and modifications through submicron and nano-scale features, achieve frictional regulation manifested in: reduction of adhesion *(Arzt et al., 2003)*, abrasion resistance *(Rechenberg, 2003)*, and frictional anisotropy *(Hazel et al, 1999).*

Squamata comprises two large clades: Iguania and Scleroglossa. The later comprises 6,000 known species, 3100 of which are referred to as "lizards," and the remaining 2,900 species as "snakes" *(Vitt e al., 2003).* They are found almost everywhere on earth. Their diverse habitat presents a broad range of

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