Chapter 1

Functional Surfaces in Mechanical Systems: Classification, Fabrication, and Characterisation

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ABSTRACT

This chapter deals with functional surfaces in mechanical systems. These surfaces are named in a multitude of ways; therefore, a classification is provided based on how the texture is designed. For a better clarification, a number of practical examples for each category are given. An overview of fabrication methods employed to produce such surfaces is presented. The numerous fabrication methods are classified based on the mechanism they employ for providing a texture. Three main categories (removing, moving, and adding material techniques) are identified, and for each of them, a number of processes are described with examples of the textures they can create. The last section of the chapter deals with surface metrology, a topic of central importance in the design and generation of surfaces for functional purposes. The process of surface characterisation is outlined, reviewing measuring instruments, classical and advanced filtering procedures, quantification methods, and eventually, providing traceability considerations.

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INTRODUCTION

Surfaces are defined as the outer boundaries of an object, separating it from the surrounding medium (Lonardo et al., 2002; ISO 25178-2, 2012). The most important physical phenomena involving exchange of energy take place on them, so it is not surprising that they play a decisive role in governing the functionality of a product (Bruzzone et al., 2008; De Chiffre et al., 2003). This is particularly true for mechanical systems in manufacturing processes and machine components, in which surfaces of different parts are in relative contact and movement. Those are called tribo-systems, from the word “Tribology,” the science studying contacting surfaces in relative motion and covering disciplines as friction, lubrication and wear (Gohar & Rahnejat, 2008). The control of these three parameters gains high economical relevance if considered that around 30% of the world energy consumption is used to overcome friction (Williams, 1994); and the costs associated with wear is in the order of percentage units (as high as 5%) of the Gross Domestic Product of developed countries (Jost, 1966; Jost, 1990; Hutchings, 1990). Over the last few decades, the worldwide expansion of micro/nano manufacturing technologies has given origin to a “rush towards miniaturization,” which contributed in a decisive manner among other things at the progress of the research about surfaces (Bruzzone et al., 2008). The manufacture and control of singular features on a surface was made possible, allowing the creation of dedicated surfaces able to provide one or more functional properties. Plateau-honed surfaces represent one of the first and maybe the most classical example of a surface presenting a texture purposely aimed to improve the tribological properties of the part featuring it. These surfaces have been widely utilized in the automotive industry since the 70s, applied particularly in cylinder liners of internal combustion engines. Plateau-honing is a double-step process: a coarse honing operation is initially performed providing a rough texture, followed by a much finer one truncating the original texture (Santochi & Vignale, 1982; Malburg & Raja, 1993). The resulting outmost texture will then be nominally flat, without main outwards peaks, but crossed by deep scratches (Figure 1). Creating a flat area gives good bearing properties to the surface and reduces drastically the so-called run-in period, in which the peaks of the surface are eliminated by attrition produced by the reciprocating action of the piston (Whitehouse, 1983). Moreover, the scratches, residuals of the coarse honing process, provide the surface with good lubricant retention properties and offer a location for debris storage. The employment of plateau-honed surfaces offers the great advantages of reducing wear phenomena and oil consumption; the process was therefore taken up with enthusiasm by car manufacturers already in the early years after its introduction (Whitehouse, 1983).
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