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Technical note

A plateau–valley separation method for textured surfaces with a deterministic pattern

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ABSTRACT

The effective characterization of textured surfaces presenting a deterministic pattern of lubricant reservoirs is an issue with which many researchers are nowadays struggling. Existing standards are not suitable for the characterization of such surfaces, providing at times values without physical meaning. A new method based on the separation between the plateau and valley regions is hereby presented allowing independent functional analyses of the detected features. The determination of a proper threshold between plateaus and valleys is the first step of a procedure resulting in an efficient division of the two regions, which can be studied separately according to their specific function. The case of a turned multifunctional profile is presented depicting the lacks in efficacy of standardized methods and therefore studied with this new methodology. Limitations of the method are eventually presented, in particular its dependence on a proper leveling of the profile beforehand.

1. Introduction

The employment of surface texturing has considerably spread over the last 30 years in the striving against friction energy consumptions and wear losses [1,2]. Since the introduction of plateau-honed surfaces for cylinder bores, the attention of researchers from both the academic world and industry has escalated leading to the development of a large number of texturing techniques and testing methodologies for specific applications [1–14]. Surface metrology, which is acknowledged playing a central role among generation, function and design [15,16], must therefore on its turn develop new methodologies for properly characterizing textured surfaces according to their functionality. Traditional filtering methods were shown creating profile distortions already in the early years after the introduction of plateau-honed surfaces [17]. Moreover, classical field parameters such as Ra, Rq or Rz are very useful in process control, but say nothing about the function of the surface [18,19]. Scott in [19] provides the enlightening medical analogy between Ra and taking a patient's temperature: a high temperature indicates that something is wrong but it does not say what. Methods for functional characterization have been widely proposed [20] and eventually the three-parts ISO 13565 was published [21–23], mainly based on German [24] and American [25] approaches. The utilization ISO 13565 has two major upsides compared to using field parameters. First of all, it provides suitable methods for characterizing plateau-honed surfaces, including the application of less distorting filters and the extrapolation of parameters that can describe separately the bearing plateaus and the lubricant reservoirs. Secondly, the methods can be directly transferred in the characterization of areal topographies [20], which have become more and more common with the introduction of optical measurement methods [26] and have recently being standardized (ISO 25178 part 2 [27] and part 3 [28]) based on the work initiated by [20] and continued by [29]. Nevertheless, ISO 13565 suffers from a major drawback: it has been ideated and designed for plateau-honed surfaces and does not rightly work for all kinds of textured surfaces. Plateau-honing consists in fact of coarse grinding followed by a honing operation. These two processes both provide surfaces with Gaussian or random distributions of heights, which appear as straight lines in a probability plot (Fig. 1). A plateau-honed surface, therefore, being a combination of two Gaussian processes, will have a probability plot composed by two straight lines of different slope (Fig. 2). This is not the case for textured surfaces presenting a deterministic pattern of lubrication pockets (or "structured surfaces" according to [3]), as it is the case of regularly spaced dimples or grooves artificially applied to a nominally flat surface [5,8,10,12,13], or of surfaces produced by an initial deterministic manufacturing process such as turning [14,30]. The aim of this article is thus to highlight problems occurring when characterizing a structured surface and to

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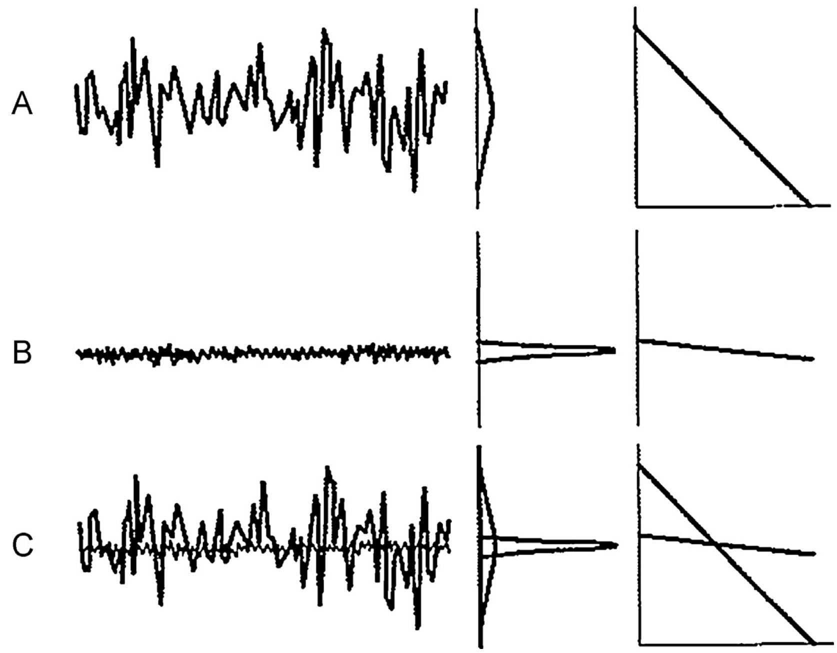

Fig. 1. Height distributions of the processes employed in creating a plateau-honed surface [23].

provide a methodology that permits the detection, separation and comprehensive analysis of the features describing a structured surface.

2. Limits of existing standards

In order to better illustrate the characterization limits of ISO 15365-2, a turned multifunctional profile is considered. Turned multifunctional surfaces are a typology of structured surfaces which have been recently introduced [30,31]. They are realized by a primary turning operation followed by highly-controlled robot assisted polishing for creating plateau regions capable of bearing loads. These surfaces could in principle assume any value of the plateau bearing area comprised between 0% (turned surface) to 100% (mirror polished surface). The turning operation will provide a deterministic pattern to the lubricant reservoirs, resulting in a material ratio curve with two major bends (Fig. 3). This aspect will highly affect the mathematical calculation of the material ratio curve parameters. For the given profile, the total height Rt = 9.01 μm, while the valley height Rvk = 9.97 μm, meaning that the valleys of the profile would be higher than the profile itself, which is physically impossible. The reason of this occurrence is explained in Fig. 4. The material ratio curve of a turned multifunctional surface profile has in the valley zone an opposite concavity compared to a plateau-honed surface, therefore the triangle, whose height is Rvk, must reach a height level lower than the minimum profile height in order to satisfy the equivalence condition. Moreover, multifunctional surfaces with plateau bearing area less than 40% risk having zero Rpk value. The least-slope 40% segment would in fact start from the first point of the bearing curve and end already in the valley region. Starting from the first point of the bearing curve would result in an equivalent triangle with null area, thus Rpk = 0 μm. The concavity change in the valley zone is even more pronounced when the material

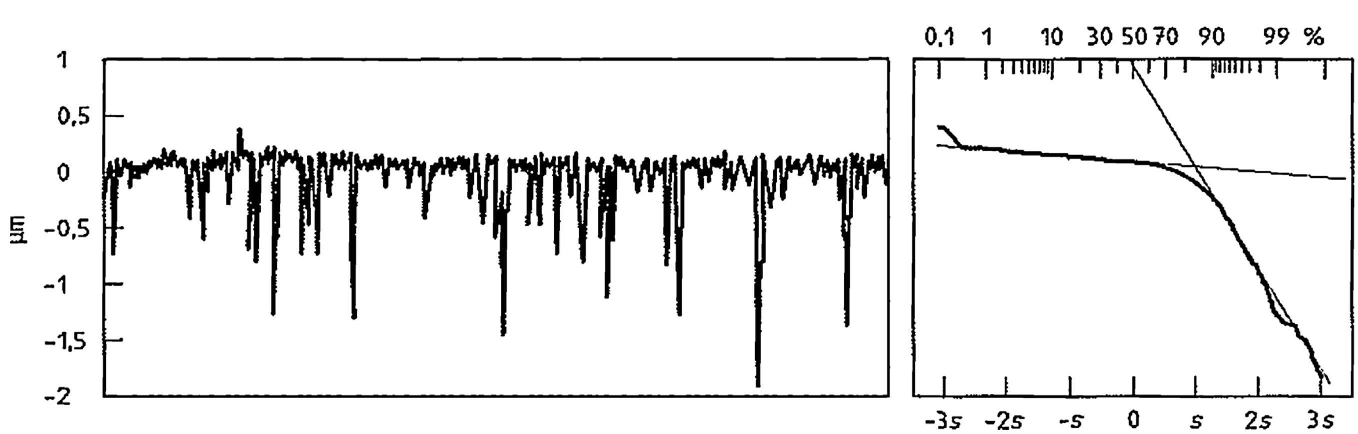

Fig. 2. Plateau-honed surface profile and probability plot [23].