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A plateau-valley separation method for multifunctional surfaces characterization

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A plateau-valley separation method for multifunctional surfaces characterization

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Abstract

Turned multifunctional surfaces are a new typology of textured surfaces presenting a flat plateau region and deterministically distributed lubricant reservoirs. 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 has been developed. After properly determining a threshold between plateaus and valleys, the two regions are divided in two distinct profiles, which can be studied separately according to the specific function.

1 Introduction

Surface texturing has been deemed being a possible solution in the striving against friction losses and wear occurrence. Lubricant reservoirs are applied to the surface without impairing its bearing capability. A typical instance is plateau-honed surfaces for cylinder liners, nowadays widely used in the automotive industry. A novel texturing technique developed by the Danish company Strecon A/S and presented in [1] and [2] introduced multifunctional surfaces realized by a primary turning operation followed by robot assisted polishing for creating plateau regions capable of bearing loads. These surfaces, referred to as turned multifunctional surfaces, could in principle assume any value of the plateau bearing area comprised between 0% (turned surface) to 100% (mirror polished surface). A major difference between the turned multifunctional surfaces and plateau-honed surfaces lies in the reservoirs distribution: while the plateau-honed surfaces are characterized by few, randomly distributed, narrow scratches; the turned multifunctional surfaces consist of a deterministic pattern of wider lubricant reservoirs. This aspect introduces new challenges regarding the surface characterization. In this paper limitations related to existing standards are depicted and a solution based on the separation between the plateau and valley region for singular profiles is proposed.

2 Existing standards

The standard currently used in the characterization of surfaces having stratified functional properties is ISO 13565 [3]. It has been designed for plateau-honed surfaces and it cannot be effectively applied to the turned multifunctional surfaces.
In fact, as already pointed out in [1] and [2], due to the deterministic nature of the turning process, the shapes of both the material ratio curve and the probability curve present two sudden slope changes. This fact affects the parameters calculation as it is shown in Figure 1: the multifunctional surface profile has a height Rz = 8.86 µm, while the valley parameter Rvk = 9.82 µm, thus higher than the profile height itself! This has no physical meaning and it is only due to the mathematical definition of Rvk.

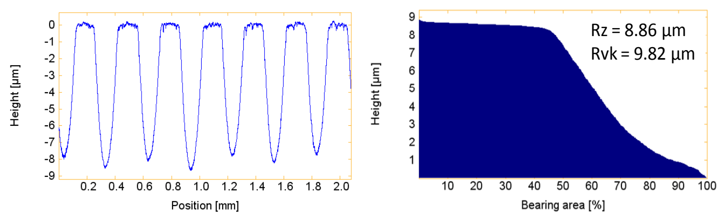

Figure 1: Multifunctional surface profile (left) and material ratio curve (right).

The particular height distribution complicates also the analyses made by means of the material probability curve. In fact, it is not possible to fit properly a line through the valley zone, biasing the parameters calculation [2]. New methods for univocally set a plateau-valley threshold are thus to be found in order to analyze those profiles.

3 Plateau – valley separation

Grabon et al. in [4] faced a similar problem in the characterization of surfaces having oil pockets applied by a burnishing technique. This texturing process created valleys with a deterministic structure, therefore the resulting material probability curve has the same shape as a turned multifunctional surface one (Figure 2, left).

In order to properly establish the plateau-valley threshold, the material probability curve is rotated by an angle ψ fit between plus and minus 4 standard deviations; the point C of highest ordinate is taken and the correspondent point on the original probability is chosen as a threshold (Figure 2, centre and right) [4].

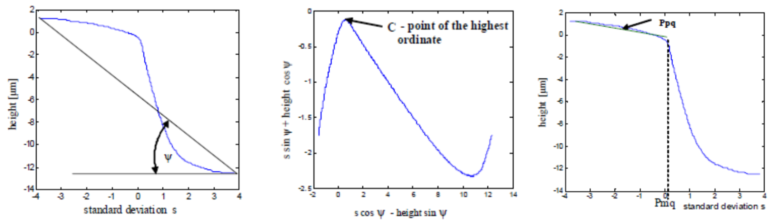

Figure 2: Typical multifunctional surfaces material probability curve (left); rotated curve (centre) and threshold determination (right) [4].

The thresholding method developed by [4] has been used in this paper for a further operation on a multifunctional surface profile. Instead of simply deriving the parameters from the material probability curve, the found threshold is used directly on the profile for separating the plateaus and the valleys. The blind application of this separation method, though, may not be satisfactory for particularly rough plateaus: small dips in the plateau regions can be clipped and included in the valley profile. The method has therefore been extended in order to recognize the starting and ending point of each plateau region: in this way the plateau local roughness will not be affected by the separation. In Figure 3 the separation method is applied to the profile in Figure 1. The direct plateau-valley separation at a threshold level would have caused the inclusion of some dips of the plateau regions in the valley profile, as for example the dips in the zoomed region.

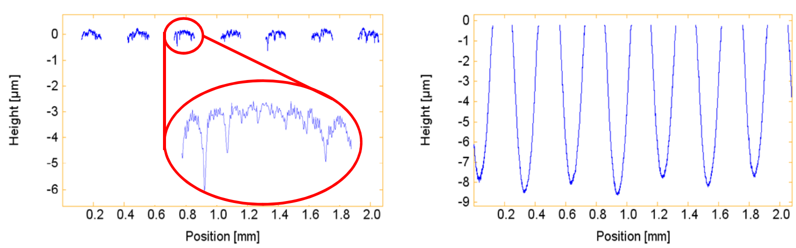

Figure 3: Separation of plateaus and valleys on a multifunctional surface.

3.1 Profile analysis

The obtained plateau and valleys profiles can be now analyzed independently according on the function of each region. Looking at Figure 3, the plateau region is the one involved in contact with another surface: the roughness defined in terms of Ra and Rq shows values of respectively 0.081 µm and 0.106 µm. The height distribution is similar to a Gaussian one, slightly skewed (Rsk=-1.21) due to deeper plateau scratches as the zoomed one. Concerning the valleys, the lubricant retention is evaluated. It is expressed as “equivalent film thickness”, thickness of the lubricant film formed between two ideally flat surfaces with the lubricant contained in the valleys. It is defined as the trapped volume per unit length divided by the evaluation length: the calculated value shows an equivalent film thickness equal to 5.488 µm.

4 Conclusions

Multifunctional surfaces having a deterministic distribution of heights in the valley region introduce new issues in surface characterization, which existing standardized methods cannot cope with. It is presented a new methodology which separates directly the plateaus and the valleys of a profile by means of a calculated threshold. Complete roughness analyses can be carried out separately depending on the function of interest.

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