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Multiscale characterisation of 3D surface topography of DLC coated and uncoated surfaces by directional blanket covering (DBC) method

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ABSTRACT

Diamond-like carbon (DLC) coated surfaces exhibit anisotropic and multi-scale characteristics, i.e., their roughness change with both scale and direction. However, most currently used standard surface characterisation parameters and methods work well only with isotropic surfaces at a single scale. This problem can be overcome by variance orientation transform (VOT) and directional blanket covering (DBC) methods. Both methods calculate fractal signatures (FSs) in different directions allowing for detailed measurement of roughness of anisotropic and multiscale surfaces. FS is a set of fractal dimensions (FDs) at individual scales, and FD is a measure of surface roughness. High FD values mean rougher surfaces. Unlike other directional FSs methods, e.g., VOT, the DBC method automatically selects scales of calculations. In this study, the DBC method was used to analyse surface topography images of DLC coated and uncoated bearing steel discs of increasing roughness. Its ability to differentiate between two groups of surfaces is evaluated. The results obtained showed that the DBC method can detect differences in roughness at different scales and directions between the DLC coated and uncoated surfaces. This work could lead to applications of the DBC method in modelling of wear and friction behaviour of DLC coated and uncoated surfaces at different scales.

1. Introduction

The topography of diamond-like carbon (DLC) coated surfaces exhibits anisotropic and multiscale nature [1], i.e., its characteristics change with scale and direction of a measurement. The surfaces are characterised using parameters provided by the American Society of Mechanical Engineers (ASME) and International Organization for Standardization (ISO) standards [2–4]. For example, arithmetic average (R_a) and root mean squared (R_q) roughness parameters were used to study the effects of surface roughness on wear rate and coefficient of friction of DLC coated surfaces [5–7]. Skewness (R_{sk}), average peak-to-valley (R_z) and core roughness depth (R_k) parameters were used to investigate the galling resistance of DLC surfaces [8]. The standard parameters work well only with isotropic surfaces, i.e., surfaces which exhibit the same characteristics in all directions. Also, they are scale-dependent, which means that their values change with a scale of measurement. Therefore, a new method that provides detailed information about multiscale surface roughness in different directions is required.

A promising solution to this problem is offered by directional fractal signature (DFS) analysis. In this analysis, FDs at different scales (i.e., fractal signature (FS)) and directions are calculated. A popular DFS method is the variance orientation transform (VOT). The method has been used in both medicine and engineering. In medicine, using x-rays of bones, the method was shown to be sensitive enough not only in detecting differences between bone texture in subjects with and without knee osteoarthritis (OA), but more importantly, in quantifying minute changes in bone texture in subjects with pre-radiographic OA and in identifying bone changes relevant for prediction of knee joint replacement and OA development [9–12]. In engineering, the VOT method could

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quantify differences between adhesive and abrasive wear particles generated at different loads and sliding distances, and characterize isotropic sandblasted and anisotropic ground surfaces [13]. The VOT method was also used in our recent study on the effects of surface topography of DLC-coated and uncoated surfaces on friction and wear in sliding contacts [1]. Our results have shown that

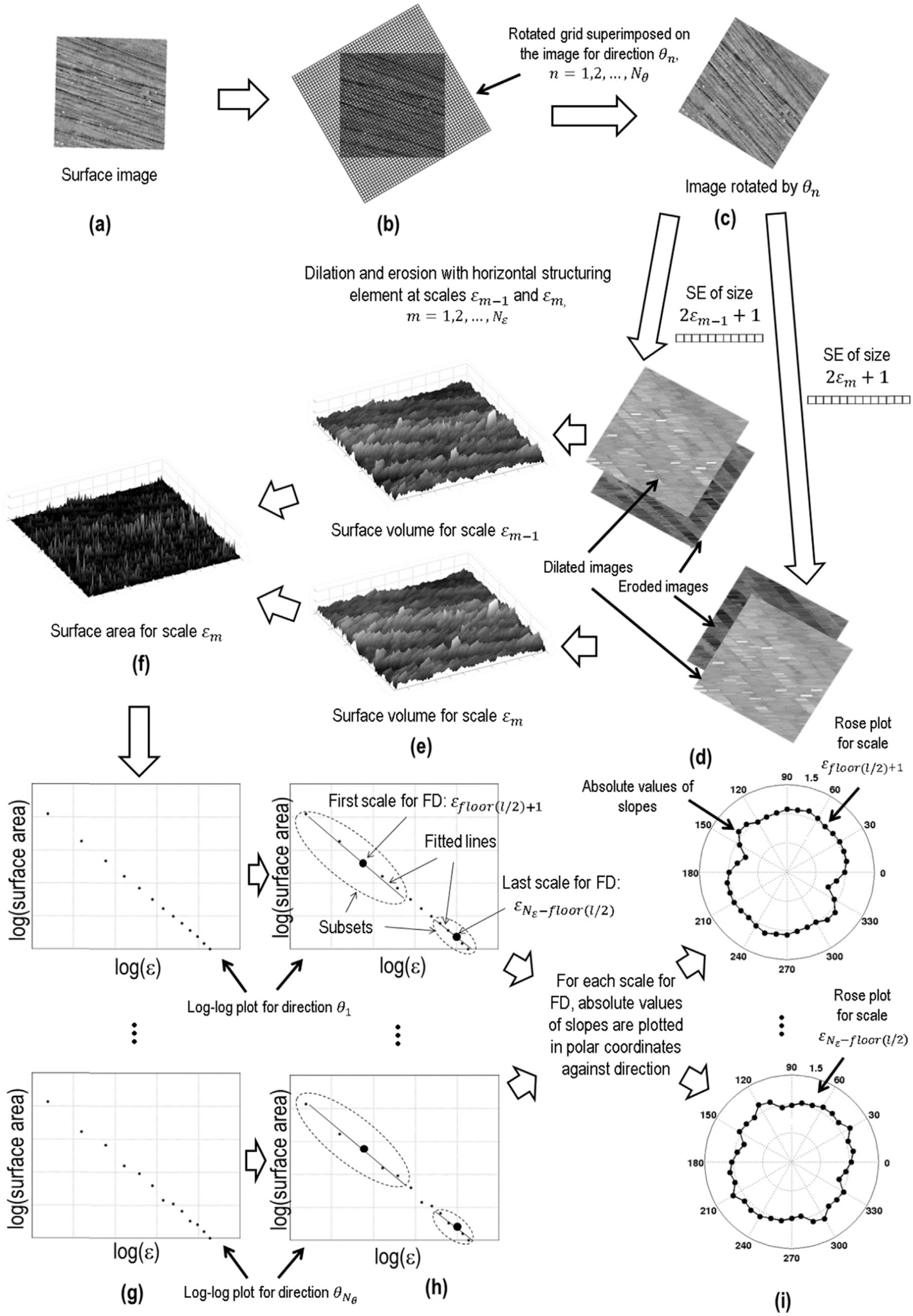

Fig. 1. Schematic illustration of the DBC method. (a) a surface range-image with grid superimposed, (b) grid rotated, (c) rotated image, (d) dilated and eroded images, (e) surface volumes, (f) surface area, (g) log–log plots, (h) lines fitted to the subsets and (i) rose plots of absolute values of slopes.