Multiresolution analysis of tribological surfaces

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1. Introduction

Multiresolution analysis (MRA) is a powerful mathematical tool based on wavelets leading to a quantitative and hence unambiguous model of tribological / engineering surfaces in terms of their roughness, waviness and profile (shape). Loosely speaking *wavelets are building blocks that can quickly decorrelate data*. [1] More precisely, wavelets form a frame (basis) for most of the function spaces and therefore are used to expand (represent) functions in these spaces.

2. Computational framework

In particular, the lifting scheme, [2] i.e., the second generation of wavelets, among other advantages allows one also to straightforwardly use standard wavelets such as the cubic B-splines, in order to numerically analyze data sets (e.g., topographical one) based on the accordingly introduced prediction and update in the forward wavelet transform at a given level of resolution.

Having obtained all the wavelet coefficients for all levels of resolution, a reconstruction and / or a decomposition of the original data immediately follows by performing the inverse wavelet transform starting from a carefully selected subset of wavelet coefficients:

3. Fingerprint of a lubricant

Surfaces are classified from a topographical point of view according to the finishing [3]. Roughness parameters in turn are implemented and standardized to aid the classification and quality control of rough surfaces [4]. At given loading conditions, the roughness of the surfaces in contact and the lubricant significantly influence the resulting wear in tribological experiments. Since MRA uniquely extracts global and local features of rough surfaces at various levels of resolution by decorrelating the topographical data into roughness, waviness, and form [5], it is to expect that a typical pattern occurring at a given level resolution within the wear scar can be unambiguously ascribed to the type of a lubricant used in a standardized wear experiment, like in high frequency reciprocating rig (HFRR) tests.

Indeed, in this contribution will be shown that topographic features at long wavelengths, i.e., at the lowest possible level of resolution, yield typical pattern structures for a given lubricant and hence the corresponding waviness can be seen as the fingerprint of that lubricant.

4. Switching between contact mechanics

The decorrelation of surface data via MRA can be also applied to a ball-on-disc configuration, within which the rough steel ball is in dry contact with the nominally flat steel disc, for a stepwise numerical removal of the roughness on the ball. Therefore at the lowest level of resolution, which yields a perfectly smooth ball, it is expected that the contact pressure distribution, together with the contact area as a function of the applied load, are given by the well-known Hertzian formulas.

In order to verify this, a combined finite element – boundary element method (FEM-BEM) developed by the authors [6] to model multi-asperity contacts is used. With this efficient numerical scheme, through the use of boundary elements, the discretization effort is kept to a minimum while the Boussinesq-Cerruti equation is numerically solved and the finite element method is aiming the computation of the influence coefficients.

Based on the resulting FEM-BEM contact pressure distribution and contact area for the MRA-smoothed ball-on-disc configuration, it is demonstrate here that Hertzian contact mechanics is indeed fully recovered at the lowest level of resolution. At the highest level of resolution, it is also proven that the ball-on-disc configuration is sufficiently well approximated by the contact mechanics of Greenwood and Williamson. Furthermore, by gradually decreasing the level of resolution, it is shown that the Greenwood-Williamson contact mechanics smoothly turns into the Hertzian.

5. References

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