coatings

Editorial

Advances in Measurement and Data Analysis of Surfaces with Functionalized Coatings

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Coatings, taking comprehensive studies into account, cannot be considered without their functional performance. When, generally, studying surfaces, a wide analysis of coatings properties is indispensable. Surfaces with functionalized coatings contain characteristic features, affecting the functional properties of many elements. Considering surface, surface roughness or, respectively, surface topography, many aspects can appear in which the whole process of surface studies contains measurement and data analysis, which can be considered as one process or separately.

There are many aspects wherein the effect of surface topography (ST) on functional properties can be large. Generally, the effect of ST on contact, e.g., stiffness [1], conductivity [2], oxidation resistance [3], adhesive [4], improvement with friction [5], lubrication [6], wear [7], corrosion [8], and fatigue [9] properties, is very high. Much relevant information can be received from the analysis of ST.

When studying the ST, even highly precise measurement equipment (devices and whole systems) may not allow receiving reliable results when raw measured data are processed erroneously [10], and properly manufactured parts can be classified as faulty and, unfortunately, are rejected. For that reason, ST can be classified as a basic issue in the process of characterization of the manufactured parts and their properties, which, generally, can support the process of control [11]. Moreover, both the measurement process and data processing have a huge, equal influence on the results obtained.

From the above matter, the motivation for presenting the current advances in measurement and data analysis of surfaces with functional properties must be found. Yet, sophisticated characterization and modeling are required to gain a comprehensive understanding of the mechanical properties of these coatings as well.

This Special Issue (SI) aims to provide a discussion for researchers to share both current and further research findings and help to promote planned research into the studies of surfaces with functionalized coatings, considering manufacturing and measurement (e.g., surface roughness), data analysis, and modeling.

Many factors can affect, unlikely erroneously, the results of ST measurement and data analysis. The main classification can be provided according to the factors that influence the accuracy of the results assessments. In that sense, the ST (measurement and data analysis) errors can be, even roughly, divided into those caused by the measuring method [12], the process of digitization [13], or software data processing [14], and errors caused by the measuring object [15] or other types of errors.

One of the types of errors is facilitated when the measurement process occurs and is often defined as noise [16]. Many types of noises can be considered in this SI, such as instrument noise or instrument white noise [17], random noise [18], phase noise [19], signal-to-ratio noise [20] or, simply, the measurement noise [21]. This was last studied previously in selected domains, e.g., the high-frequency measurement noise [22], which in most cases is caused by vibrations.

Generally, an 'engineering surface' can be analyzed as a surface that is composed of a large number of wavelengths of roughness that are superimposed on each other.

Therefore, analysis of surface topography, based on the frequency methods, when, e.g., a high-frequency noise is separated, is common. Despite many scientific articles on ST analysis being published, valuable information on how to deal with selected types of measurement and data analysis errors is rare and the current state of this area of knowledge is not fully unified.

Another problem, which is often met in the field of surface metrology studies, is the end-effect, or, respectively, edge-effect. This problem is especially crucial when digital filtering is proposed for the analysis of surface roughness. In general, it is extremely difficult to determine the signal received by filtering at both ends of the profile and detail. It is often stated that edge-effect in ST filtration seems to be a considerable problem when applying digital filtering; nevertheless, it was also indicated that this issue affects the analysis of surface roughness with least-square methods, e.g., least square fitted polynomial planes of n-th order [23] and various approaches based on its modifications [24]. Recursive implementation of Gaussian filter seems to be a reasonable alternative [25]. For an areal and profile application, it was assumed in the ISO standards, as well [26]. Moreover, many popular algorithms were proposed for the characterization of ST and, correspondingly, managing the edge-effect problem, such as a two-dimensional discrete spline filter [27] and high-order spline [28]; approaches with a typical example of an extension of the spline filtering [29], many different combinations of boundary conditions of the spline filter [30], wavelets, or its combinations [31] were thoroughly analyzed and compared to provide satisfactory end-data characterization. Some proposals were presented by modification of raw measured data, such as fulfilling the dimples or features generally located near the edge of analyzed detail [32]. It was also found that both surface features' (e.g., dimples) size and distribution can significantly affect the accuracy of the roughness evaluation as well [33]. All of the issues abovementioned can be especially valuable in the reduction of the measurement and data processing errors; nevertheless, all of them require mindful users.

Evaluating the surface coatings' properties is correlated to the characterization of selected features. Very popular in the analysis of ST are, as commonly called, feature-based algorithms [34] or feature-based procedures [35], used for segmentation [36] of the measured surface topography area. Additionally, methods based on multi-scale analysis are also popular in surface metrology [37]. The purpose of using multiscale methods is to more accurately determine the functional correlations between the parameters of machining processes and the created surface topographies [38]. Moreover, many surface topography properties can be received when multi-scale studies are proposed, such as anisotropy that can influence surface function and can be an indication of processing [39].

Surface topography characterization can be supported by many algorithms, schemes, approaches, and procedures, such as those from commercial software. Often used and improved are those methods based on frequency analysis, such as the frequency spectrum (FS [11]) scheme. Further, one of the proposed, commonly available solutions is to analyze the Power Spectral Density (PSD) graph. According to the definition, in its two-dimensional form, PSD has been designated as the preferred means of specifying the surface roughness on the draft international drawing standard for surface texture [40]. The process of dry machining, including cooling using the Minimum Quantity Cooling Lubrication (MQCL), has proven that by using a PSD technique, it is possible to characterize the turning according to the applied cooling methods [41]. The applicability of PSD was also improved with Auto-Correlation Function (ACF) to be especially valuable in the detection of the high-frequency measurement errors of honed cylinder liner surfaces [42].

Reducing errors in measurement and, correspondingly, in the whole process of data analysis, should depend on the type of data studied. Usually, research on the ST is proven directly to the selected types of surfaces. In the proposed SI, in fact, there are no limits on the types of surfaces that can be characterized by their functional performance. Except for tribological properties, such as rolling contact fatigue [43], or, e.g., anti-corrosion properties [44], the surface (topography), and its coatings, are widely studied for implant applications [45]. From the biomedical coatings, many advances indicate increasing in this field of study [46]. Further issues are placed with the environment, where eco-friendly perspectives with biodegradable coatings are searched for by many scholars [47,48]. All of the medical studies seem to be different from those with the tribological point of view that many various requirements must be met, such as antibacterial [49] properties. Another issue, the biocompatibility of implants [50,51], can be mentioned as a major problem that can hinder the clinical application of surfaces. Some actions, such as, e.g., chemical bonding [52], can improve the bioactivity of selected types of surfaces.

Widely studied and presented in the coatings research area are thin film improvements. They are classified as a promising candidate for, e.g., spintronic applications [53], glass substrates [54], considering semiconductors [55] or magnetic and gas sensing [56], and thermoelectric [57] or optical [58] properties. Thin film coatings have a wild range of applications [59] that are suitable for the proposed SI area of study.

Presentation of plenty of algorithms and procedures, currently, requires from surface metrology general guidance on how to deal with different measuring problems without losing the validity of the methods applied. The more approaches appear, the more suggestions on how to use them should be provided. Moreover, increasing the area of a variety of surface topographies considered with functionalized coatings performance makes the SI even more required to be proposed. From that matter, I trust that the issues raised in this editorial, concerning and, respectively, collecting of all of the recent advances in the measurement and data analysis of surfaces with functionalized coatings will be found as useful and provide valuable information for all of the surface metrology areas.

Conflicts of Interest: The author declares no conflict of interest.

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