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Effect of the tracing speed and span on roughness parameters determined by stylus type equipment

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ABSTRACT

In this work, the effect of the scanning speed and the spacing in a roughness measurement was studied on the reference specimen using “TALYSURF CLI 1000” Profilometer. Microfiltration with ratio of 2.5 μm and Gaussian filter 800 μm was used. “TalyMap Platinum” software was used to analyse the data. Contact types of measurements were taken with inductive gauge using 2 μm radius stylus. Design of Experiments (DOE) and Analysis of Variance (ANOVA) tools were employed in this study to conduct the experiments and validate the results. The profile parameters R_a, R_q and R_z and the Surface parameters S_a, S_q and S_z were selected as the response variables for the roughness. The study reveals that the scanning speed has the significant effect on only R_a, R_z and S_a and S_z measurements and the spacing has the significant effect on all the Profile and surface measurements.

1. Introduction

Surface roughness is generally defined as deviations of a surface from its ideal shape. It significantly influences tribological characteristics, viz. friction and wear, of a surface apart from its contact resistance, viz. thermal and electrical, fluid flow through pipes/tubes and over body surfaces, viz. ship hull exterior etc. Surface roughness also influences noise and vibration control, dimensional tolerances of parts in assemblies etc. Hence, quantification of surface roughness is essential and is generally done through a series of roughness parameters. However, proper and accurate quantification of surface roughness is still a challenge due to its repeatability and consistency issues. The values of various surface roughness parameters are prone to vary due to factors like type of technology used in measurement, viz. contact or non-contact type, contact stylus profile, type of filters, reflectivity of the surface in optical methods and resolution and speed of scanning. The objective of this paper is to study the effect of scanning speed and spatial resolution on roughness parameters based on 2D and 3D profile measurements.

The motivation of the work was from the observed variations in surface roughness values in the same sampling area on a sample with respect to scanning speed and resolution while taking surface profiles using a TALYSURF CLI 1000 3D surface profilometer. These deviations called for a systematic study to establish an optimum combination of scanning speed and resolution to produce repeatable surface profiles over the same sample area. This work would help in setting up the measurements for repeatable 2D line and 3D surface profiles in a general purpose profilometer offering a wide range of scanning speeds and spatial resolution. Although various works have been reported in literature on surface roughness, there are practically nil literature on the effect of scanning speed and resolution on surface roughness parameters.

Mignot and Gorecki [1] conducted compared the defect-of -focus optical and classical contact stylus techniques of surface roughness measurements. They found the optical method to be more accurate as compared to the stylus method, especially in low roughness samples due to

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limitation lateral resolution of stylus. Hillmann et el. [2] measured and correlated the R_z (ten-point mean roughness), P_t (total height of the profile) values with the stylus profile and stylus contact pressure. Within the range P_t, R_z < 1 µm, considerable systematic errors were reported with the stylus method. Engineering surfaces are comprised of a range of spatial wavelengths. Filtering techniques are commonly adopted to separate the different wavelength components into well-defined bandwidths. Raja et al. [3] studied multi-resolution analysis by more robust filters. Sedin et al. [4] studied the influence of tip size on surface roughness measurements by atomic force microscopy. In this study the influence of R_q as function of tip size was probed over a length scale of 1000 nm on quartz. R_q was observed to decrease when the tip size increased for size scans ($\leqslant$500 nm). The larger tips were did not come into contact with the lowest points on the quartz surface.

Surface finish is one of the most common measures of surface quality of metal parts and a wide variety of methods and parameters are been developed to measure it. Significant differences in arithmetic average roughness root mean square roughness and peak to valley roughness were obtained when comparing the data from the various topographic measuring instruments [5]. Different field techniques for assessing discontinuity roughness were studied; the value of this data and a new laser profilometer design for field application was reported. A large difference between the quality of field data that is commonly collected was reported as compared to the ability to measure, record and quantify discontinuity profile conditions in the lab [6]. The actual performance and the calibration of the profilometer system was investigated through various tests including measurement/positioning repeatability tests of individual components, measurement accuracy tests, measurement sensitivity tests and system natural frequency testing [7]. The Conscan software was employed to capture high quality surface topography images of tribometer wear tracks. The advantage of using the Conscan to measure metrological data from a given surface is that once the image is acquired, unlimited profiles can be extracted in many locations and directions [8]. A laser sensor based system has a scanning area of 200 by 120 mm and a reasonable vertical dimensional correlation between scanned parts (coins, screws, washers, and fibre optic lens moulds) was achieved. Testing of the system was also discussed, including the limitations of the profilometer and possible improvements to the system [9]. Gregory Morrow [10] reported that the relative roughness between sites was maintained for the different classes of instruments. The class one instruments (ARRB Walking profilometer and Z-250) produced very similar results. The Riley significantly underestimated the roughness on rougher surfaces, whilst the MERLIN provided consistently accurate results, when compared to the class one instruments [10]. The pavement profile data collected by four profilometers used by SHRP's (Strategic Highway Research Program) Long Term Pavement Performance Program (LTPP) was compared. Three of the profilometers were identical; the sensors of the fourth were closer together. The purpose of the comparison is to determine if the profilometers can collect repeatable data with respect to each other as well as individually at a given site, and whether they are collecting accurate data [11]. Stylus profilers are the most common instruments used today for roughness measurement; however, more recent techniques such as scanning tunneling microscopy STM and Atomic force microscopy AFM have presented improved spatial resolution and are, therefore, suitable for capturing finer details [12]. All techniques mentioned here have a common limitation, which is their inability to detect internal envelopes such as those caused by delamination [13]. This drawback may prevent researchers from obtaining valuable information regarding, for example, lubricant retention mechanisms [14].

This paper reports the results from the study of the effect of scanning speed and spatial resolution in surface roughness measurement by contact stylus surface profilometry. Design of Experiments (DOE) approach was used to arrive at the test matrix and data analysis was carried out following Analysis of Variance (ANOVA) approach. The following Section 2 discusses the experimental methods. The results are discussed in Section 3 followed by conclusions in Section 4.

2. Experimental procedure

2.1. Measurement method

A series of experiments on a 6 µm roughness UKAS Reference Specimen 112/1534 were designed following Design of Experiments (DOE) approach and carried out. TALYSURF CLI 1000 surface profilometer with a 2 µm radius inductive type contact stylus sensor was employed for generating the scanned line and surface profiles. Inductive gauge was employed due to its high resolution and high accuracy. Working principle of Inductive gauge in the profilometer is illustrated in Fig. 1. Contact is established between the diamond tipped stylus attached to a lever arm and the specimen mounted on an automatically movable table. While both the stylus and specimen surface are in contact, the specimen is moved at a pre-defined scanning speed and spatial resolution. Vertical movement of the stylus as it travels across peaks and valleys on the surface is converted into an electrical signal by the inductive gauge which, in turn, is converted into a 2D or 3D surface profile depending on the dimensionality of table movement [15]. Subsequent to generating the line and surface profiles 'TalyMap Platinum' software was used to analyse the scanned profiles. Microfiltration with ratio of 2.5 µm and Gaussian filter 800 µm was used. The test specimen and the profilometer are shown in Figs. 2 and 3 respectively.

2.2. Test matrix

Design of Experiment (DoE) technique of full factorial randomized design was followed in order to conduct the experiment and validate the results. The design was based on two factors, one at 7 levels and other at 3 levels with full factorial randomized design. Scanning speed and spacing were taken as the factors and the profile and surface measurement data were taken as response variables. The