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Characterisation of surfaces produced by robot-assisted polishing (RAP)

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Abstract

A RAP sample with five belts was manufactured covering the range of (11-169) µm R_a. The belts were measured using a stylus, a variable focus microscope and a white light interferometer (WLI). Results show that such a cylindrical sample manufactured using RAP is a potential reference artefact for traceability purposes.

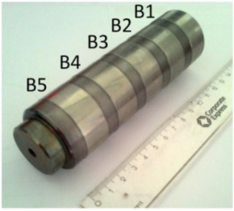
Introduction

Measurements on polished surfaces are a challenge to available instrumentation. Manually polished surfaces are characterized by large variations due to intrinsic non-uniformity of the process with percentage surface roughness variation in the range of 16 % to 36 % for the roughness level of (6-50) nm R_a [1]. On the contrary a cylindrical sample, manufactured using fully automated robot-assisted polishing, is characterized by surface uniformity and regularity, which enables measurements with good repeatability and overall lower uncertainties.

RAP takes place on a lathe provided with a polishing module mounted on a robot [2]. A round RAP sample encompassing five belts (B1-B5) was produced (fig.1 - left) with each belt polished to a higher finish level, from 169 nm R_a for B1 to 11 nm R_a for B5. The sample was used in an investigation involving a stylus instrument as reference and two optical 3D microscopes (fig. 1 – right). The surface evaluation was done using SPIP 6.1.0 software.

Calibration of cylindrical sample on stylus instrument

The stylus instrument, a Form Talysurf 50 (FTS), is traceable via a PTB calibrated reference (Halle- KNT4070- 26 nm R_a). The background noise of FTS was checked through an optical flat and correctness of its tip was checked using an atomic force microscope



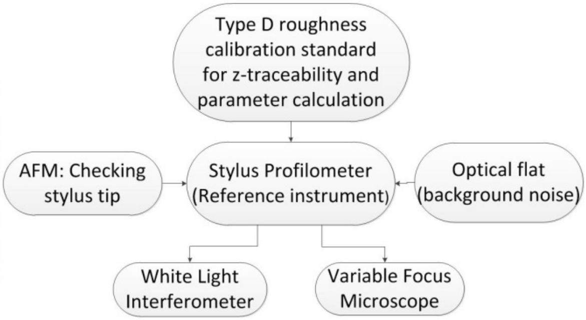


Figure 1: left: Sample configuration, right: Measurement methodology

(AFM) (fig.2). Each belt was measured 12 times along the axis of the sample. Measurements were performed using a λ_c Gaussian filter equal to 0.8 mm and a λ_s filter equal to 2.5 µm following ISO11562 [3].

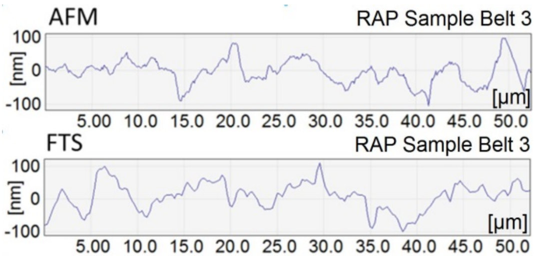


Figure 2: comparison of FTS and AFM profiles

Each series were examined for outliers. Table 1 shows the R_a values for each belt. Uncertainties were calculated using GUM considering the following contributors:

[u_{cal}] Calibration uncertainty of the reference;

[u_b] Uncertainty due to background noise;

[u_{sur}] Repeatability of the measuring process due to the relocation of the measurement area;

[u_{rep}] Instruments vertical calibration uncertainty. The expanded uncertainty U was calculated as:

Ra(nm)	B1	B2	B3	B4	B5
R_a	169	52	31	15	11
u_{cal}	0.7	0.7	0.7	0.7	0.7
u_{rep}	0.6	0.6	0.6	0.6	0.6
u_b	1.7	1.7	1.7	1.7	1.7
u_{sur}	8.5	2.4	1.6	0.5	0.6
U	17	6.2	5	4	4

Table 1: Uncertainty budget for FTS

$$U = \mathrm{k}\sqrt{u_{cal}^2 + u_{rep}^2 + u_b^2 + u_{\mathrm{sur}}^2}$$

A coverage factor $k = 2$ was used. Summary of the uncertainty budget for each belt is shown in table 1. The standard uncertainties related to surface variation are in the range of 8.5 nm R_a (B1) to 0.5 nm R_a (B4). Percentage variations of the surface roughness are in the range 5 % (B1) to 6 % (B5). Reference expanded uncertainties are in the range of 4 nm R_a (B5) to 17 nm R_a (B1).

Measurements using optical instruments

The first optical instrument was an Alicona Infinite Focus microscope. Different belts were measured using 100× objective in manual mode without polarizer with 10 nm height resolution and 89 nm lateral resolution. Each scan covered an area of 146 µm × 111 µm which was corrected for bow and outlier removal. 3D visualization of the results is shown in figure 3 for the three finer belts. The other optical instrument is a Zygo New view 200 - 3D Coherence Scanning Interferometer (CSI) which is a kind of WLI. The instrument has 2 nm height resolution and minimum lateral resolution of 0.3 µm. The objective 20× was used. Scans were corrected for bow and outlier removal.

Discussion

Figure 3 depicts a 3D surface visualization comparison between Alicona and WLI for the three fine belts (B3-B5) and an AFM image is provided as a stylus representative

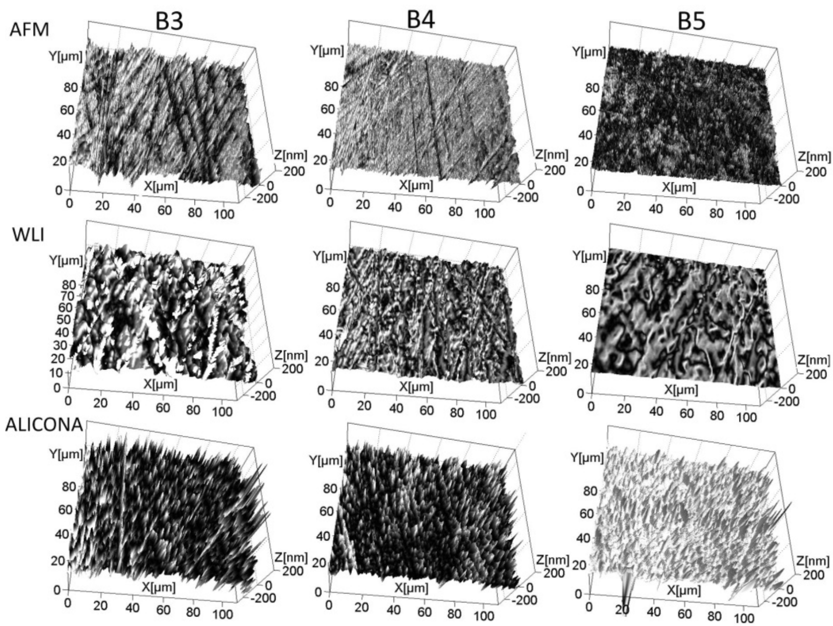


Figure 3: 3D visualization of RAP sample by AFM, WLI and Alicona

instrument. The areal size for all instruments is 110 µm × 90 µm. AFM scans were made parallel to the axis of the cylindrical sample. The crosshatch structure of RAP is clear and the improvement of the surface is evident after each polishing step. WLI has limitations to catch the details of B3 because it is rather rough for this setup but toward the finest surface it seems that scans are getting reasonably fine and detailed while the Alicona microscope does not show a considerable change in progress from B3 to B5. Although the magnification was at its highest possible for this instrument (100×), but it seems that the noise level is rather high. Figure 4 shows a comparative quantification of roughness in terms of S_a (3D arithmetic average roughness). The comparison shows that WLI follows AFM with a maximum error of 28 % in the lower side while Alicona reads higher than AFM up to 3 times.

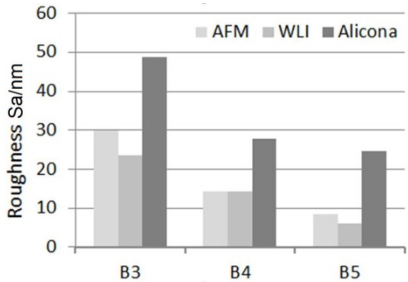


Figure 4: comparison of roughness

Conclusion

The surface roughness variation of the round sample measured using stylus instrument was in the range of (5-6) % which is comparable to that of fine roughness calibration standards [4]. The investigation shows that such a cylindrical sample manufactured by RAP process is a potential reference artefact for traceability purposes in connection with optical measurement of surface roughness.

Acknowledgment

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