Multi-scale analysis of high precision surfaces by Stylus Profiler, Scanning White-Light Interferometry and Atomic Force Microscopy

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Abstract: The relevance of three different techniques (Stylus Profiler (SP), Scanning White-Light Interferometry (SWLI) and Atomic Force Microscopy (AFM)) to characterise the topography of aluminium and hard steel surfaces, was investigated. Evolution of roughness parameters (Ra and Rt) was analysed according to the evaluation length. Asymptotic Ra values showed good agreement between data measured by SP and by AFM. SWLI data show important discrepancies with the other instruments due to their sensitivity to surface morphologies. AFM is the best instrument to detect micro-roughness but is limited by its maximum evaluation length. SP (2D measures) is, therefore, a good compromise to characterise surface morphologies over a wide spatial range.

Keywords: multi-scale analysis; roughness; high precision turning; SP; stylus profiler; SWLI; scanning white light interferometry; AFM; atomic force microscopy.

Reference to this paper should be made as follows: Jouini, N., Gautier, A., Revel, P., Mazeran, P-E. and Bigerelle, M. (xxxx) 'Multi-scale analysis of high precision surfaces by Stylus Profiler, Scanning White-Light Interferometry and Atomic Force Microscopy', *Int. J. Surface Science and Engineering*, Vol. x, No. x, pp.xxx–xxx.

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1 Introduction

Roughness measurement is the common method of characterising the morphologies of manufactured surfaces and, therefore, of estimating their functionalities. To ensure the relevant roughness characterisation, two main choices have to be made: a relevant measurement technique and a relevant roughness parameter or set of parameters. The latter allows the discrimination of surfaces generated by a similar manufacturing process, or by different processes. Even if a relevant roughness parameter is determined by a powerful numerical method, the topographic data have to be measured by a suitable measurement technique. Thus, the measurement technique used for morphological characterisation of surfaces should be chosen according to the functional properties of the surface (Lonardo et al., 2002). However, roughness values of a given surface can be significantly different when they are measured by different techniques (Leach and Hart, 2002; Poon and Bhushan, 1995).

In this context, the specific purpose of this work is to compare three measurement techniques Stylus Profiler (SP), Scanning White-Light Interferometry (SWLI) and Atomic Force Microscopy (AFM)) on two different surface morphologies: a finishing stage (Ra ≈ 120 nm) and a super finishing one (Ra ≈ 9 nm).

SP is the most common instrument to measure surface profiles (Vorburger, 1992). It measures the surface heights with a resolution that depends on the tip radius. However, due to contact and the applied load, the stylus penetrates elastically (eventually plastically) into the surface, depending upon its radius, the mechanical properties of the substrate and the topographical geometries of the surface, leading to a significant influence on the measurement results (Poon and Bhushan, 1995; Zahwi and Mekawi, 2000). Considering measurement speed, the stylus instrument takes a long time to get a frame image because of the poor frequency response characteristics of the stylus-spring system (Stout and Blunt, 2000).

Optical methods have the advantage of being able to measure without contact and thus preserve the surface integrity. Hocken et al. (2005) have presented a wide variety of instruments which have different capabilities and limitations. SWLI provides an image that depends on the number of pixels of the CCD camera. Moreover, this technique is sensitive to reflectivity and surface morphology (slope of profile). However, it is a very fast technique in comparison with SP. Brinksmeier and Riemer (1998) have used AFM in the field of diamond turning. Due to its high resolution, AFM is a good method used for process control and quality assurance in applications where nanometric accuracy is required (MEMS, etc.). However, the low image scale and measurement time can limit the usage of this technique.

In comparison with optical and stylus methods for measurement of surface texture, Vorburger et al. (2007) have observed discrepancies between interferometric and stylus instruments for surface roughness measurement in the 50 nm to 300 nm range of Ra.

According to Wennerberg et al. (1996), surfaces of hard industrial materials, which generally present high slopes, are better evaluated by a stylus instrument. In the case of soft materials, optical methods are often preferred because the SP underestimates the roughness due to tip radius and contact pressure. However, for arithmetic roughness about Ra = 0.1–0.8 μm, Ohlsson et al. (2001) show one objection to interferometric microscopy: the Ra is overestimated, because this instrument can induce localised artefacts (of the order of 0.1–0.5 μm) caused by high local surface slopes. By examining the performance of commercial SWLI, Gao et al. (2008) have showed that most instruments report errors when used in regions close to a discontinuity or those with a surface gradient that is large compared to the acceptance angle of the objective lens.

After measurement, a numerical treatment is applied to the raw data to characterise the surface roughness. To determine the roughness parameters, several methods and treatments can be used. Sata et al. (1985) have used the spectrum analysis technique to analyse the roughness profile of a turned surface. For characterising three-dimensional topography, Dong et al. have used statistical methods (Dong et al., 1994a) and autocorrelation function analysis (Dong et al., 1994b). According to Stachowiak and Podsiadlo (2001), the problem with these methods is that they provide parameters that strongly depend on the scale at which they are computed. Recently, multi-scale analysis methods were developed to characterise the roughness, such as the fractal method and surface decomposition by Continuous Wavelet Transform (CWT). According to Grzesik and Brol (2009), CWT can be useful to analyse roughness profiles generated by cutting processes. However, de Brunner and Kadiyala (1999) show that the choice of wavelet basis has a considerable effect on multi-scale surface decomposition. Among the various methods of numerical characterisation, the use of multi-scale analysis of the surface roughness data seems to be preferable because of its ability to characterise surface properties in a simple and efficient way (Stachowiak and Podsiadlo, 2001).

In this study, a multi-scale approach is used; the decomposition of profiles is adapted to the roughness parameters of the manufactured surfaces (Bigerelle et al., 2007a, 2007b; Gautier et al., 2007).

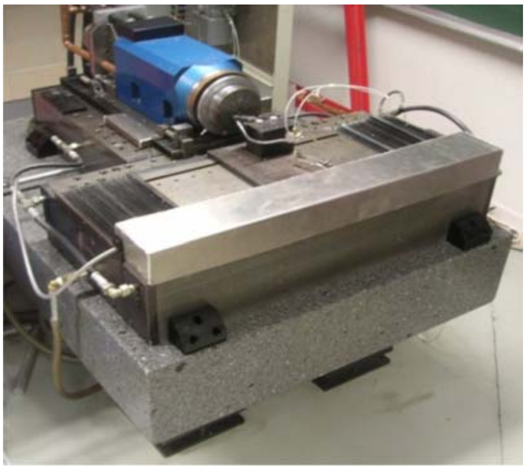
The first part of this paper presents the machined surface samples, the measuring instruments and the applied data post treatment. In the second part, the evolutions of the arithmetic and peak to valley roughness parameters (Ra and Rt) in function of the evaluation scale are presented for each instrument and each surface. Finally, the results are discussed.

2 Materials and methods

2.1 Investigated surfaces

All samples were machined by high precision turning in facing operations with different cutting parameters (Table 1). The high precision machine (Figure 1) is a prototype lathe, designed by Snecma™ Motor, located in an air-conditioned room. The two slides-ways are fixed on a massive granite block (1.5 tonne), itself resting on four self-levelling pneumatic isolators. A magnetic-bearing spindle (with active control) is located on the *z*-axis slide-way (Khanfir et al., 2005). The slide-ways are guided by hydrostatic-bearings, offering low friction, high stiffness and high damping. The straightness of both slides is better than 0.3 μm over a displacement of 100 mm. Displacements are controlled by two optical encoders of 4 nm resolution controlled by an accurate computer numerical control system.

Figure 1 High precision turning machine (Roberval Laboratory) (see online version for colours)



Two different surface morphologies were used to characterise the roughness of high precision machined surfaces:

- The first material is a pure aluminium (99.5%; measured by semi-quantitative micro-analysis (on SEM)). Three different zones were machined on a disc of 30 mm diameter (Figure 2) with different feed rates and cutting speeds (Table 1).
- The second material is a hard steel (AISI 52100) with a hardness of 61–62 HRC. Three samples (discs of 30 mm diameter (Figure 3)) were machined with different feed rates (Table 1).

Table 1 Machining conditions

Turning conditions	*Surface type*					
	AISI 52100 steel			*Pure aluminium*		
	Sample 1	*Sample 2*	*Sample 3*	*Zone 1*	*Zone 2*	*Zone 3*
Cutting tool	cBN	cBN	cBN	Mono-crystalline diamond		
Depth of cut (μm)	50	50	50	10	10	10
Spindle speed (rpm)	2400	2400	2400	1250	1250	1250
Cutting speed (m/min)	340	340	340	115	75	35
Feed rate (μm/rev)	6.2	12.5	18.7	4.8	9.6	24

Figure 2 Schema of pure aluminium (99.5%) surface: top side and area

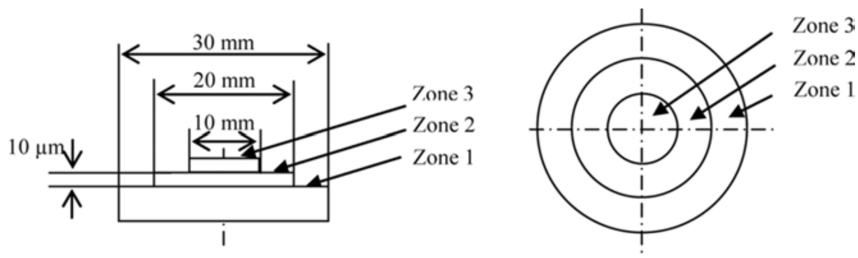
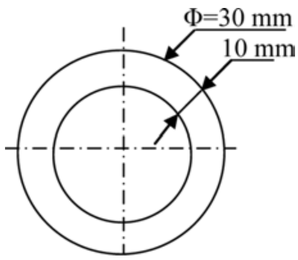


Figure 3 Schema of hard steel (AISI 52100) sample



The spindle speed was constant during all facing operations. Thus, the cutting speed decreases along the radial position. However, the facing operation was limited to short strokes; therefore, the cutting speed could be considered as constant for each zone.

2.2 Measuring instruments

The surface roughness of high precision machined surfaces was measured by SP, SWLI and AFM. SP gives 2D profiles, whereas AFM and SWLI give 3D images.

2.2.1 Stylus Profiler

Surface roughness measurements by SP were carried out with a KLA-Tencor™ (P-10 model). The stylus has a conical diamond with a tip radius of 2 μm. A low load (50 mN) was applied to preserve the integrity of surface. Thirty roughness profiles were recorded perpendicular to the grooves. A 100 nm sampling interval was used for all samples. The measuring range was 1 mm for the aluminium sample and 2 mm for the hard steel sample. The vertical resolution was 0.075 nm.

2.2.2 Scanning White Light Interferometry

The Zygo™ NewView 200 is a SWLI that uses Frequency Domain Analysis (FDA) to generate quantitative 3D images of surfaces (de Groot and Deck, 1994); measurements use a white light filter based on a centre wavelength of 600 nm, with a bandwidth of 125 nm. The interference patterns were recorded by a CCD camera; each measurement contains 320 × 240 data points. Three objectives with the following magnifications: ×2.5, ×10 and ×50, were used and three images were recorded for each magnification. The scan size and sampling interval were fixed by the magnification of the optical system. For the magnification of ×2.5, the sampling interval was 8.8 μm in the both directions. The lateral resolution of the microscope was limited by the numerical aperture of the objective and the vertical resolution was less than 1 nm.

2.2.3 Atomic Force Microscopy

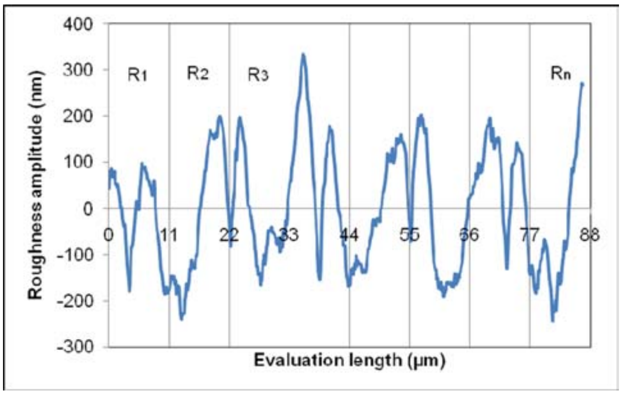
Experiments were performed with a commercial Atomic Force Microscope (Dimension 3100, Nanoscope IIIa from Veeco™). The AFM measurements were carried out in tapping mode using silicon probes (TESP, Veeco); the nominal curvature radius of the probe was 20 nm. Three sets of images were recorded (512 × 512 pixels) at different horizontal scales: 1 μm, 10 μm and 88 μm.

2.3 Multi-scale analysis

In this study, all surfaces were flattened by a third degree polynomial fit to remove the form of the surface. Two amplitude roughness parameters were chosen, namely the arithmetic (Ra) and the total amplitude roughness (Rt) also called “Peak to Valley”. Indeed, Ra is the most commonly specified parameter for surface finish measurements and Rt is used for maximum amplitude that describes the overall roughness of a surface (sensitivity at extreme values).

The objective of the proposed data treatment was to calculate the roughness amplitude parameters Ra and Rt as a function of the evaluation length. Each parameter was calculated with a decreasing evaluation length. Firstly, all roughness profiles were taken perpendicular to the grooves. Then the roughness parameters were computed for each set of lines and for some evaluation lengths as follows: each line was split off in equal segments according to the evaluation length (Figure 4). The local roughness parameter was computed for each segment by taking account of the average value as a referenced line. Then, the final roughness parameter of a line was computed as the median value of the segments. The roughness parameter of a set of lines was computed as the median value of the lines.

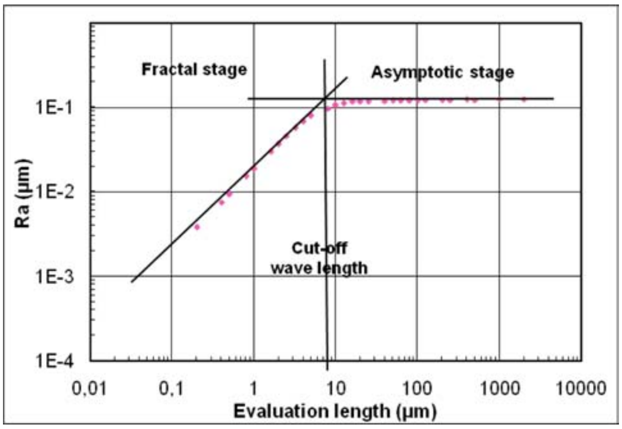
Figure 4 Methodology of multi-scale roughness parameters computing according to the evaluation length (segment = 11µm) (see online version for colours)



For all instruments, each roughness parameter is the mean value of three set of lines measured at different locations.

Figure 5 presents the arithmetic Ra value of ten measurements carried out by SP at different locations of the hard steel sample as a function of evaluation length in log–log coordinates. This evolution shows a bifractal behaviour (Rosén et al., 1996) with two different linear slopes in log-log scales, and a cut-off wavelength corresponding to the junction of two stages, that identify the transition between the fractal stage and asymptotic stage. Ra does not depend anymore on the evaluation length in asymptotic stage.

Figure 5 Evolution of roughness parameter (Ra) versus the evaluation length, showing bifractal behaviour and cut-off wave length



According to Bigerelle et al. (2007a), Rt parameter presents two stages: one linear (log–log coordinates) and one logarithmic, respectively, the fractal stage and the extreme values stage. Moreover, it presents one particular stage called the radius stylus tip stage result of interaction between radius tip and material.

3 Results

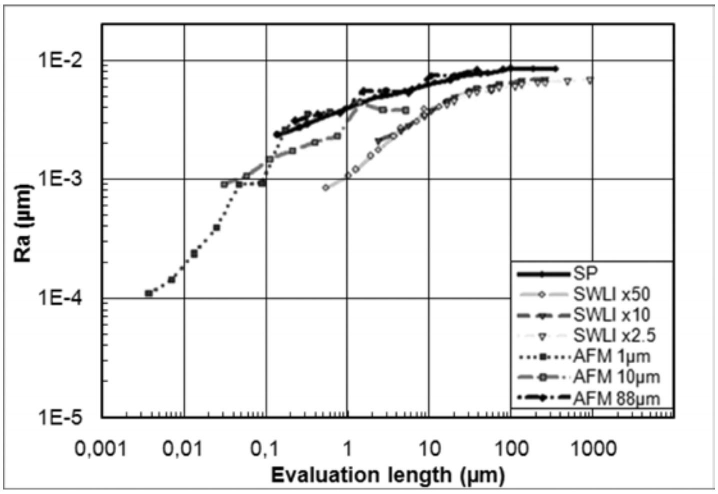
3.1 Aluminium surfaces

3.1.1 Capability of each instrument

In this section, the influence of the evaluation length on the roughness parameters Ra and Rt is studied to evaluate the reliability of each instrument.

Figure 6 shows a bifractal aspect with two different linear stages (fractal and asymptotic stages) for all measuring instruments except AFM at lower image scales (1 μm and 10 μm).

Figure 6 Influence of the evaluation length on the average roughness (Ra) from first zone of aluminium disc (see Figure 2)

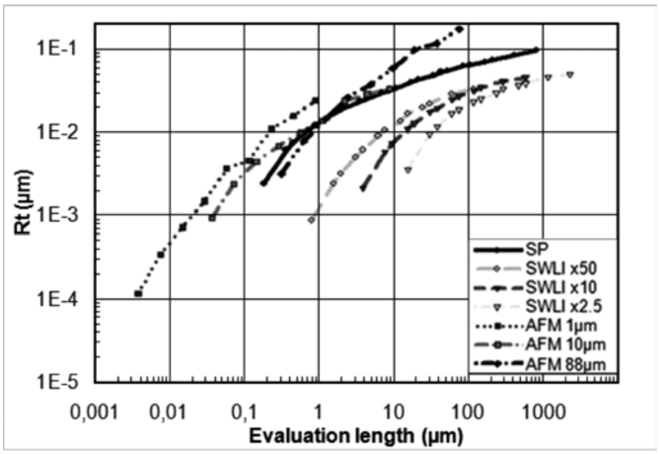


In the asymptotic stage, SWLI results do not depend on magnification; the Ra value (7 nm) is reached for an evaluation length of 100 μm. However, for both SP and AFM (88 μm scale) the Ra value (9 nm) is reached for different cut-off frequencies: 100 μm for SP and 50 μm for AFM.

Regarding the Rt parameter, Figure 7 shows that the longer the evaluation length, the higher the Rt value. Indeed, no asymptotic stage occurs. This is due to the number of data points used to evaluate the Rt. Even if the true value of Rt becomes constant, its numerical evaluation will be highly sensitive to the number of data. The probability of detecting high peaks or deep valleys increases with the number of points, and is also proportional to the evaluation length. That is why Rt still increases with the evaluation length passing over the fractal stage, but with a decreasing slope (for proof, see appendix). Otherwise, for a fixed evaluation length, the Rt value increases with magnification, because a higher resolution increases the ability to detect micro-peaks and micro-valleys, leading to higher roughness values.

The same analyses were carried out on zone 2 and 3 and led to similar results.

Figure 7 Influence of the evaluation length on the total roughness amplitude (Rt) from first zone of aluminium disc (see Figure 2)



3.1.2 Comparison of measurement instruments

In the asymptotic stage, Ra values show good agreement between the data measured by SP and AFM 88 µm. However, SWLI results are slightly lower than those of SP and AFM (Figure 6). In the fractal stage, the data measured by SP are reliable.

Figure 7 shows that Rt does not reach an asymptotic stage for all instruments. SWLI results are lower than those using SP and AFM.

3.2 Hard steel surfaces

3.2.1 Capability of each instrument

Measurements and multi-scale analyses used for aluminium samples were also applied to hard steel surfaces. The variations of feed rate have no significant effect on the roughness parameters chosen and measured. Thus, only measurements carried out on sample 1 are presented.

Figure 8 presents fractal and asymptotic stages for all measuring instruments except AFM (1 µm scale). In the asymptotic stage, SWLI presents good agreement between different magnifications. The Ra value (190 nm) is reached for an evaluation length of 10 µm. However, for both SP and AFM (88 µm and 10 µm scale) the Ra value (120 nm) is reached for different cut-off frequencies: 10 µm for SP and AFM (88 µm scale), 6 µm for AFM (10 µm scale).

Figure 9 shows the influence of the evaluation length on the Rt parameter. With SWLI, the longer the evaluation length, the higher is the Rt. Indeed, the probability of detecting peaks or valleys increases with magnification and, therefore, Rt value increases. To validate the previous observation, the evolution of the Rt parameter according to the sampling interval for a fixed evaluation length (88 µm) was computed on different SP profiles. Figure 10 shows that the Rt value decreases when the sampling interval increases. Indeed, a higher resolution increases the ability to detect micro-peaks and micro-valleys and, therefore, leads to a higher Rt value.

Figure 8 Influence of the evaluation length on the average roughness (Ra) from first sample of hard steel disc (see Figure 3) (see online version for colours)

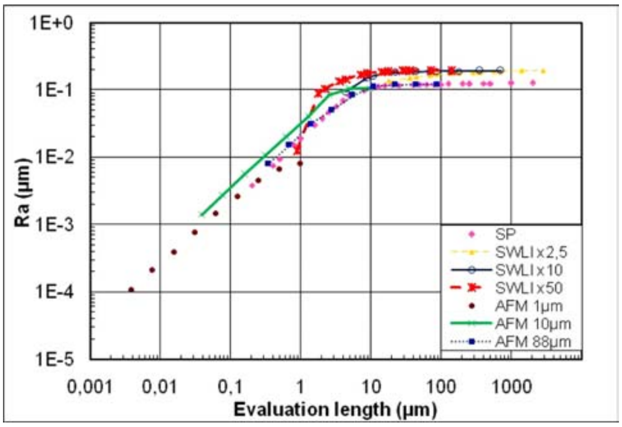


Figure 9 Influence of the evaluation length on the total roughness (Rt) from first sample of hard steel disc (see Figure 3) (see online version for colours)

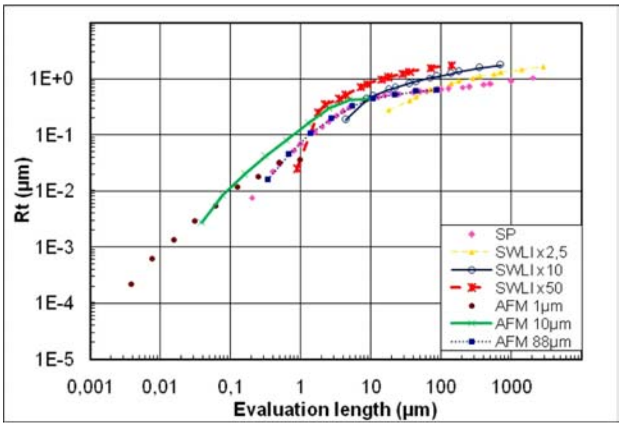
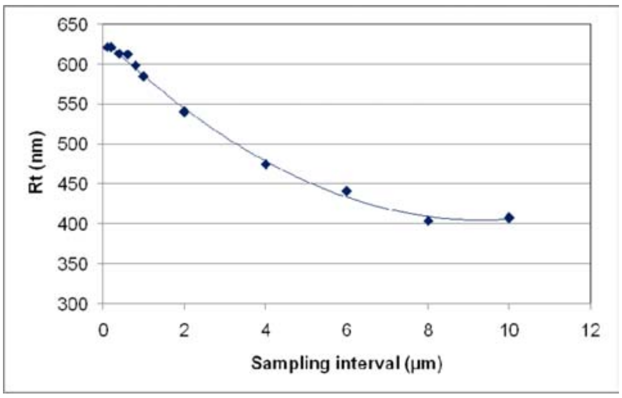


Figure 10 Evolution of Rt parameter according to sampling interval for 88 µm evaluation length on different SP profiles (hard steel surface)



3.2.2 Comparison of measurement instruments

In the asymptotic stage, Ra values show good agreement between SP and AFM (88 μm and 10 μm scales); the Ra value is evaluated at 120 nm. However, SWLI results are much higher than those using SP and AFM (Figure 8); Ra is evaluated at 190 nm.

Figure 9 shows that Rt does not reach the asymptotic stage for all instruments. SWLI results are higher than those using SP and AFM.

4 Discussion

4.1 AFM and SP

In the Ra asymptotic stage, SP and AFM 88 μm present a good agreement and similarity of results on two different surface morphologies: aluminium surfaces with low roughness (Ra ≈ 10 nm) and hard steel surfaces with arithmetic roughness (Ra ≈ 120 nm). However, for AFM 1 μm and AFM 10 μm for aluminium surfaces and AFM 1 μm for hard steel surfaces, the asymptotic stage is not reached because the evaluation length is not enough to reach the Ra asymptotic value. Thus, AFM is a good technique used to measure micro-roughness but is not always able to evaluate macro-roughness. Due to its relatively low radius tip (2 μm) and long evaluation length, SP provides a good estimation of macro-roughness. It can detect the surface profile from 10 μm to 3 μm evaluation lengths. As consequence, AFM and SP are two complementary techniques.

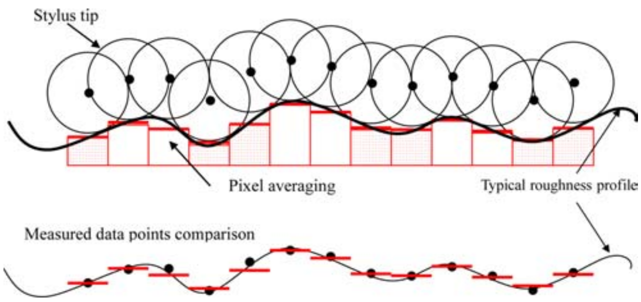
4.2 SWLI and SP

In the case of aluminium surface, the Ra values measured with SWLI are slightly lower than AFM or SP results. In the case of hard steel finished surfaces, the Ra value is much higher than those of AFM or SP values. From these observations two different behaviours of SWLI measurements have to be explained: the slight underestimation in the case of aluminium surface and the overestimation of hard steel surface.

4.2.1 Under-estimation of the roughness profile

According to Gautier et al. (2007), the under estimation of the roughness parameters Ra and Rt may be due to a ‘smoothing’ effect (spatial pixel averaging) induced by the measure principle of SWLI. Each measured point of the topographic picture is issued from a pixel of the microscope CCD camera; therefore, each pixel gives an average height of the viewed area. AFM and SP measure the surface heights point by point and, therefore, without averaging. Figure 11 shows the smoothing effect of SP and SWLI on a typical roughness profile. Due to the radius tip, SP could not fully fit the roughness profile and slightly smoothed it. Due to the averaging of the pixel measure, SWLI also smoothes the roughness profile. By comparison of measured data points, the smoothing effect is higher for SWLI than for SP.

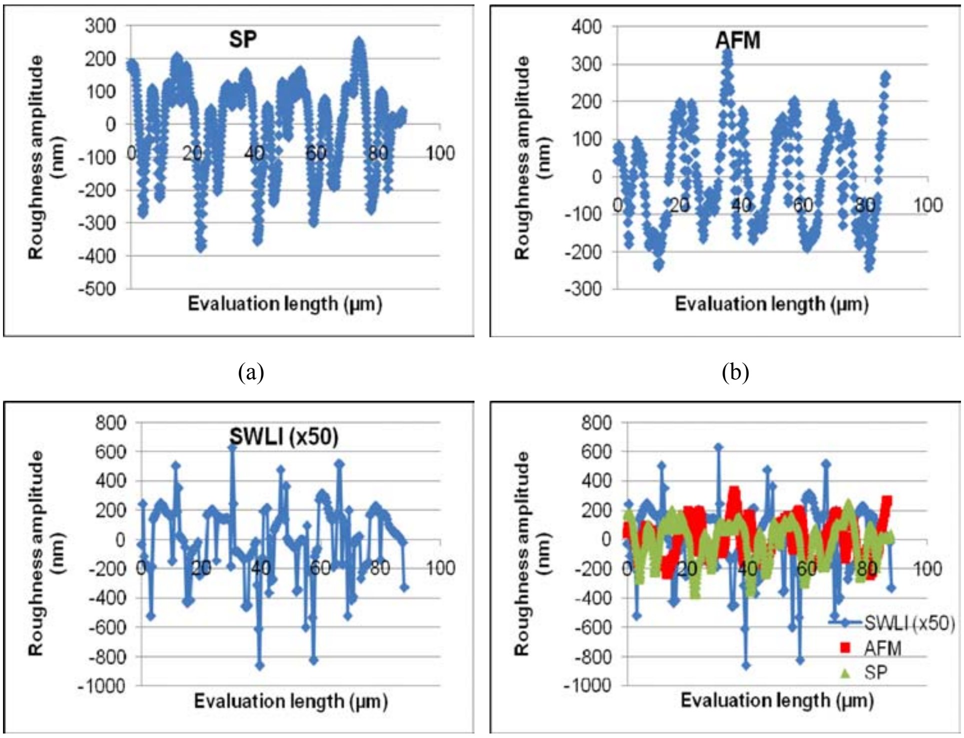
Figure 11 Comparison between SP and SWLI on a typical roughness profile (see online version for colours)



4.2.2 Over-estimation of the roughness profile

In order to check the results of the roughness parameters of the measuring instruments obtained by multi-scale analysis, representative profiles of hard steel surface were extracted with an evaluation length of 88 µm. Figures 12 and 13 show the comparison of roughness parameters of SP, AFM and SWLI profiles. The results confirm the good agreement and similarity between SP and AFM results, and also the clear difference from that of the SWLI.

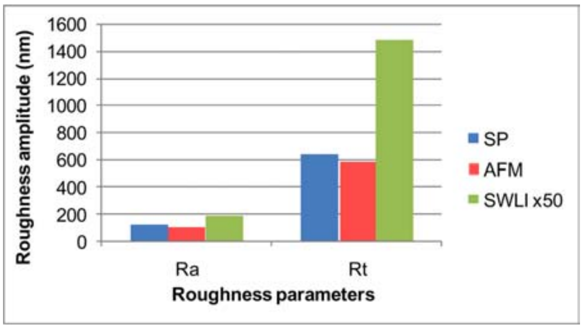
Figure 12 Comparison of SP, AFM and SWLI (×50) profiles: (a) SP; (b) AFM; (c) SWLI ×50 and (d) comparison between profiles (see online version for colours)



(a) (b)

(c) (d)

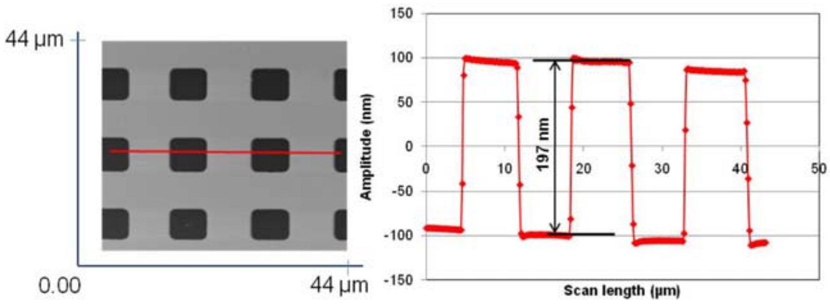
Figure 13 Comparison roughness parameters of SP, AFM and SWLI (×50) profiles (see online version for colours)



The overestimation of the roughness amplitude corresponds to an artefact generated by the SWLI. SWLI uses FDA mode. FDA is a mathematical method for processing complex interferograms in terms of phases and spatial frequencies. It is a natural and logical extension of the Phase-Shift Interferometry (PSI) mode (de Groot and Deck, 1994). The PSI mode measures the surface profile by determining the phase variations of the light reflected normally from the surface and converting them into height variation. However, the phase is wrapped within the interval $[-\pi, \pi]$. This leads to a 2π phase ambiguity problem (Tiziani, 1997). The wrapped phase interval $[-\pi, \pi]$ corresponds to a surface height range of $\pm \lambda/4$ (de Groot, 1993). The monochromatic interferometry is only able to correctly measure height variation, between two adjacent pixels, less than a quarter of the wavelength (Creath, 1987, Harasaki et al., 2000). In principle, FDA solves the problem of phase ambiguity (de Groot et al., 2002).

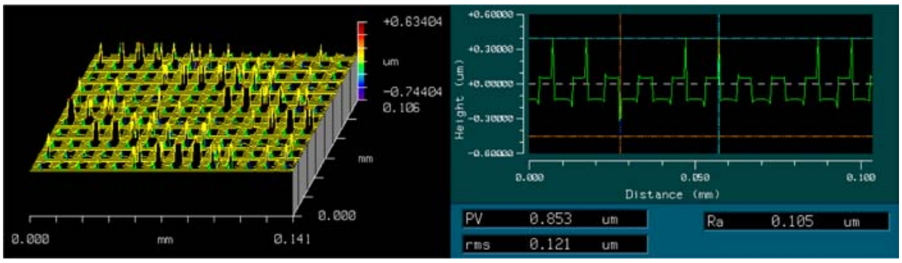
However, at some sharp edges, the solution can be imperfect due to distortions in the white-light interference patterns. To validate the previous observation, a height step standard including several steps with the same height of 200 nm produced by Digital Instrument™ was measured by AFM and SWLI (Figure 14). Artefacts on some points of the surface produced around the step discontinuity were observed in Figure 14(b). Each height artefact is about 0.3 µm. Our experiments confirm the results obtained by Ohlson et al. (2001) in the order of artefacts (0.1–0.5 µm).

Figure 14 Profiles obtained by AFM (a) and SWLI (b) on a standard (25 µm pitch and 200 nm height) (see online version for colours)



(a)

Figure 14 Profiles obtained by AFM (a) and SWLI (b) on a standard (25 µm pitch and 200 nm height) (see online version for colours) (continued)

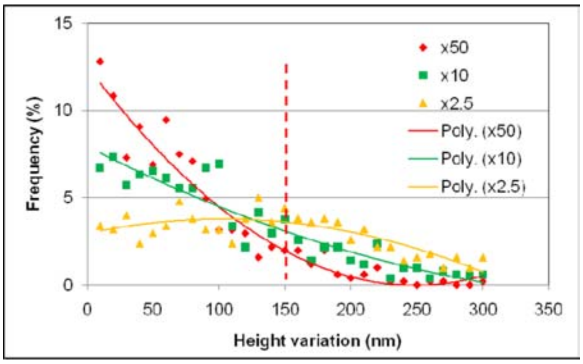


(b)

Figures 12 and 14(b) show the sensitivity of SWLI in measurements of surfaces presenting some sharp edges for height variation greater than 150 nm (corresponds at a quarter of the wavelength).

In order to estimate the percentage of height variation (higher than 150 nm) that could be incorrectly measured by the SWLI, a representative AFM profile is analysed as follows: firstly, AFM profiles are flattened. Secondly, height amplitudes are averaged on an interval corresponding to the sampling interval of the SWLI (pixel). Then, the amplitude ranges between two adjacent steps defined previously are computed on the whole evaluation length (88 µm). Figure 15 represents the distribution of the amplitude ranges obtained by AFM for the different sampling intervals according to the 3 SWLI magnifications. It shows that the larger the magnification, the higher is the low height variation percentage (height variation <50 nm). The percentage of height variations higher than 150nm is small for high magnification (×50: ≈ 8.6%; ×10: ≈ 18.5%; ×2.5 ≈ 35.4%). These results present good agreement with Figure 12(c): indeed, 7% of points are incorrectly measured (artefacts), this value is of the same order as the percentage of height variation higher than 150 nm (8.6%).

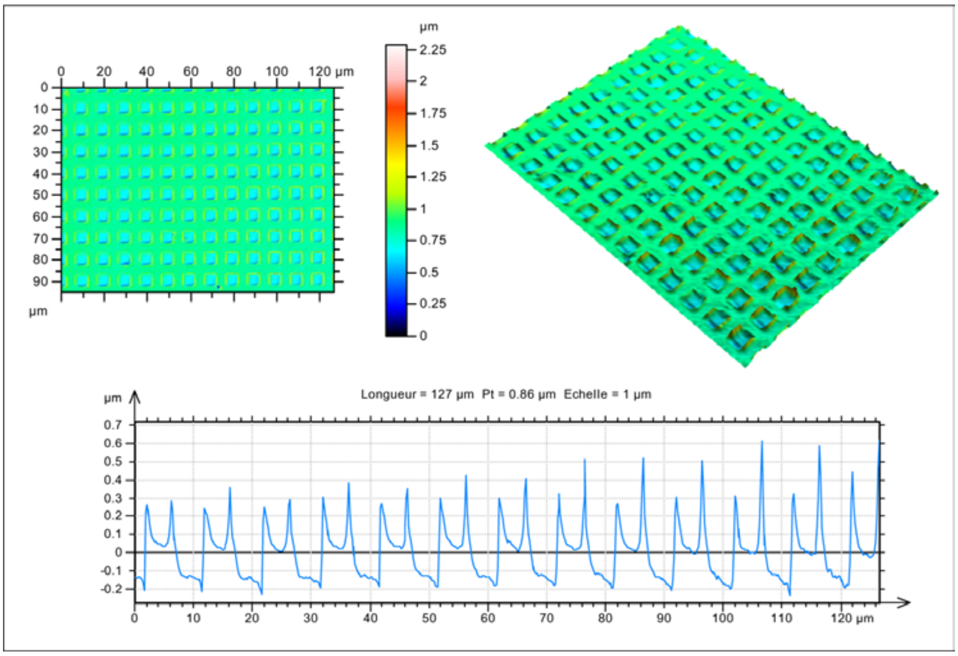
Figure 15 Distribution of height variations obtained by AFM extracted at SWLI with different magnifications; Poly: Polynomial of order 2 (see online version for colours)



This analysis allows checking if the measurements carried out by SWLI introduce artefacts that overestimate the roughness parameters.

In conclusion, the 'phase ambiguity' is always present in measurements carried out by SWLI using FDA. Moreover, Figure 16 shows that another interferometric microscope (Veeco™ NT9300) uses the Vertical Scanning Interferometry (VSI) mode, and is also sensitive to sharp edges. These results confirm that the measurements carried out by interferometry are sensitive to sharp edges whatever the chosen mode. The results of the comparison of measuring instruments obtained with AISI 52100 and aluminium are not transferable to hard and ductile materials respectively. Indeed, the results depend on the material, the cutting tool and the interaction tool/material.

Figure 16 Standard (25 µm pitch and 200 nm height) profile obtained by VSI mode (see online version for colours)



5 Conclusion

For super finished surfaces, all instruments reach the asymptotic stage, except AFM, for low image scale. In the asymptotic stage, SP and AFM give similar results (Ra ≈ 10 nm). For SWLI, roughness parameters values are slightly lower than AFM and SP due to a smoothing effect.

For finished surfaces, all instruments reach the asymptotic stage, except AFM, for low image scale. In the asymptotic stage, SP and AFM give similar results (Ra ≈ 110 nm). For SWLI, the roughness parameters values are much higher than AFM or SP, due to sensitivity of the FDA mode to surfaces with local height variations larger than $\lambda/4$ (≈ 150 nm).

Due to the fact that SWLI underestimates or overestimates the surface morphologies, interferometry must be used cautiously. AFM is also the best instrument to detect micro-peaks and valleys. Unfortunately, the evaluation length of AFM could not be large enough to characterise the Ra asymptotic value. For longer evaluation lengths, SP presents very good results and allows to characterise macro-roughness. Finally, SP (2D measures) is a good compromise to characterise surface morphologies over a wide spatial rang.

Acknowledgements

Contract grant sponsor: CETIM (Centre Technique des Industries Mécaniques) foundation, Senlis (France) (Nouvelles méthodes d'analyse des états de surfaces: de la caractérisation à la recherche de paramètres pertinents).

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Appendix A

As far as Rt is concerned, it can be expected that the probability to record high peaks (i.e., high value of $Y_{\max}$) or deep valleys (i.e., small value of $Y_{\min}$) is all the more important as far as the evaluation length l increases. As differs on the *Ra*, it can be stated that two stages limits are reached a (log-log linear) and log-log logarithmic stage. At the larger scale (asymptotic stage on the *Ra*), the linear relation does not hold meaning the fractal concept cannot be applied. If the fractal concept always hold whatever the scale, this means that the roughness amplitude of the surface will always increase. It can be postulated that the transition stage I – stage II is linked to a loss of fractal properties of the profile. After the stage II, no 'memory' occurs in the profile and the one gets a pure random process and must be analysed with appropriate tools. In fact, a new concept has to be introduced: we postulate that after the fractal stage, the surface become stationary in a statistical sense (ergodicity) meaning that the mean amplitude *Ra* of the surface stays constant (meaning that the Rt is calculated in term of mathematical integration without including the sampling effect i.e., with an infinite integration points). However, including the sampling effect, the fluctuation occurs due to inherent stochastic processes and the magnitude of the extremes values increases with the number of sampling points. The surface roughness parameters Rt(l) are measured at given observation scales l and the question is "what will be the value of these parameters on a higher scale that was not measured and what are the errors in the prediction?". The answer to this question is of major interest in high finish surface control because, surfaces are rarely measured in their totality (high time consuming, limitation of scanning length of profilometers…). In this case we supposed that the scanning length is over the fractal stage (around 10 µm, see Figure 5) and then one must model the Stage II. We can possess an analytical probability density function of $Y_{\max}^{x}(10\,\mu\text{m})$ and $Y_{\min}^{x}(10\,\mu\text{m})$ of the maximal and minimal local roughness amplitude and thus estimated on the scale l = 10 µm (statistical modelling). Supposing that the evaluation length is twice that the initial one i.e., one wants to estimate $Y_{\max}^{x}(20\,\mu\text{m})$, then, by supposing that at this scale data are independent, the maximal amplitude is equal to: $Y_{\max}(20\,\mu\text{m}) = \max(Y_{\max}^{x}(10\,\mu\text{m}),\quad Y_{\max}^{x'}(10\ \ \mu\text{m}))$. for two possible values of x and x'. From an algorithmic point of view, this means that one takes randomly values that follow $Y_{\max}^{x}(20\,\mu\text{m})$ and an other one, then the maximal values of these two value gives a possible value of the maximal roughness measured on 20 µm. Extending this, the values of $Y_{\max}^{x}(kl)$ are obtained by taking the maximal value from k values of $Y_{\max}^{x}(l)$. This seems then to claim that no asymptotical values can emerge for $R_t^x(l) = Y_{\max}^{x}(l) - Y_{\min}^{x}(l)$ due to the sampling effect only, even if the asymptotical stage is reached for the *Ra* (end of fractal stage). However, as we have shown, a log-log relation is found, meaning that after a sufficient length value, the increase of Rt can be neglected at the point of surface functionality.