View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Online Research Database In Technology

Technical University of Denmark

# The effect of scattered light sensor orientation on roughness measurement of curved polished surfaces

**Pilny, Lukas; Bissacco, Giuliano; De Chiffre, Leonardo**

*Published in:*
Proceedings of the 14th euspen International Conference

*Publication date:*
2014

Link back to DTU Orbit

*Citation (APA):*
Pilny, L., Bissacco, G., & De Chiffre, L. (2014). The effect of scattered light sensor orientation on roughness measurement of curved polished surfaces. In Proceedings of the 14th euspen International Conference (pp. 233-236). euspen.

DTU Library
Technical Information Center of Denmark

**General rights**
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# The effect of scattered light sensor orientation on roughness measurement of curved polished surfaces

L. Pilný, G. Bissacco, L. De Chiffre
*Technical University of Denmark, Department of Mechanical Engineering, Denmark*

lupi@mek.dtu.dk

**Keywords: Surface roughness, measurement, light scattering**

## Abstract

Light scattering is a method for surface roughness measurements well suitable for use in a production environment thanks to its fast measurement rate, insensitivity to vibrations and to small misalignments. The method is however affected by several other factors. In this paper, the effect of angular orientation of a commercial scattered light sensor on roughness measurements of polished cylindrical surfaces with crossed surface lay is investigated to document the robustness of the method.

## 1 Introduction

Light scattering is an area-integrating method for non-contact measurement of surface roughness, described in ISO 25178 part 6 [1]. The method measures a representative area of the surface as a whole and provides numerical results based on area-integrating properties of the surface texture [1]. In this investigation, a commercial sensor type OS500-32 from OptoSurf GmbH was used. The instrument working principle is based on a non-coherent light beam of 0.9 mm in diameter illuminating the measured surface, reflection of the incident light from the surface slopes in spatial directions, and its acquisition within ± 16º angular range with a linear detector array. From the distribution of the acquired scattered light intensity, a number of statistical parameters describing the surface texture are calculated, where the *Aq* parameter (variance of the scattered light distribution), is used to characterize the surface roughness [2]. Due to the area-integrating measurement principle and unidirectional sensor detector, the measurement output is sensitive to the orientation of the detector relative to the surface texture directions and form. Surfaces having unidirectional texture (e.g. turning, grinding) are properly characterized with the detector perpendicular to the surface lay [2]. A mathematical model of the sensor measurement principle with the given restriction of unidirectional lay was derived in [3], showing the effect of surface curvature on *Aq* and formalizing a correction term to suppress the effect in the case of unidirectional lay. Surfaces with multidirectional lay (e.g. polishing, cross grinding) should be characterized in multiple directions, ideally with the sensor detector perpendicular to the main texture directions. In combination with the simultaneous presence of surface curvature, the optimal sensor orientation is not obvious and its effect on the measurement output is unknown.

The effect of angular orientation of the sensor detector on roughness measurements of cylindrical polished surfaces with crossed surface lay was investigated and is documented in this paper.

## 2 Measurement procedure and data analysis

Three surfaces with different surface roughness (see table 1) polished by Robot Assisted Polishing (RAP) on a cylindrical specimen of 38 mm in diameter were measured with the scattered light sensor and a stylus profilometer. The scattered light sensor was mounted in an indexable fixture 5 mm above the measured surface, performing the measurements in twelve angular positions with 15° intervals, where 0° refers to the detector collinear and 90° perpendicular to the specimen axis (see figure 1). Surface texture directionality was characterized using the angular spectrum analysis tool in SPIP™ software by Image Metrology on 1 mm × 1mm area topography measurement taken with a stylus profilometer Form Talysurf from Taylor Hobson. Stylus tip radius of 2 µm, resolution 0.25 µm in X tracing direction collinear to the specimen axis, 10 µm in Y, 2nd order Least Mean Square fit for form removal, $\lambda s$ 2.5 µm and $\lambda c$ 0.8 mm filtering were used prior to the analysis. Additionally, surface photographs were taken with an optical microscope to visually assess directionality of the surface texture (see figure 1).

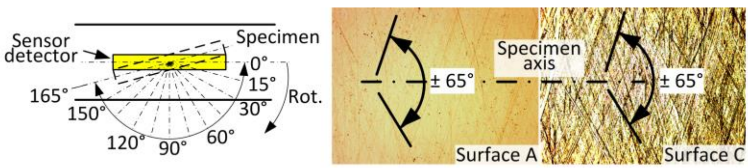


Figure 1: Orientation of sensor detector (left) and photographs of surfaces A and C.

## 3 Results and discussion

The angular spectrum analysis revealed two dominant texture directions with constant angle of ± 65° relative to the specimen axis for all tree investigated surfaces, which was affirmed by the surface photographs (see figure 1). The predominant effect of surface curvature can clearly be seen in figure 2 on the measurements on the finest surface A (see table 1), where *Aq* increases by 139 % from 0° to 90° of the sensor orientation. This is caused by the additional slope due to the surface curvature widening the scattered light distribution (see figure 3), thus enlarging *Aq* (variance of the distribution).

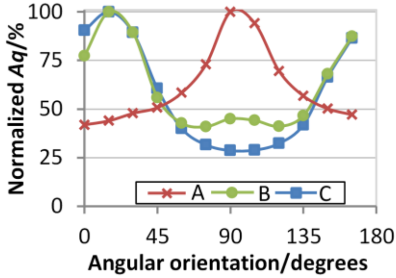


Figure 2: Normalized *Aq* in 12 angular sensor orientations on surfaces A, B, C. Normalized $Aq = [(Aq/Aq_{max}) \cdot 100]$.

In opposition to the curvature effect, texture directionality has a predominant effect on measurements of surfaces with higher roughness, causing a decrease in *Aq* by 42 % for surface B and 68 % for surface C for the sensor orientation from 0° to 90° (see table 1 and figure 2). This is due to the relative orientation of the unidirectional detector with respect to the spatially reflected light from the surface slopes causing a change in the distribution of the acquired light on the detector, thus affecting the *Aq* value (see figure 3). The reduction in intensity on surfaces with higher roughness is due to its portion scattered outside the range of the sensor (± 16°). Simultaneous effect of the two factors, texture directionality and curvature, can be seen in figure 2 in the measurements on surface B. With the initial sensor displacement *Aq* drops due to the effect of the texture directionality, while it rises at around 90° of the sensor orientation due to the curvature with nearly constant absolute intensity *I* acquired.

Table1: Change in measured intensity *I* and *Aq* as the effect of sensor orientation.

| Surface | *Ra*/µm | Change in *I*/% | Change in *Aq*/% |
|---|---|---|---|
| A | 0.012 ± 0.001 | 20 | 139 |
| B | 0.032 ± 0.002 | -4 | -42 |
| C | 0.178 ± 0.010 | -50 | -68 |

Where change in % is calculated as the measured value at $\{[(90° – 0°)/0°] \cdot 100\}$

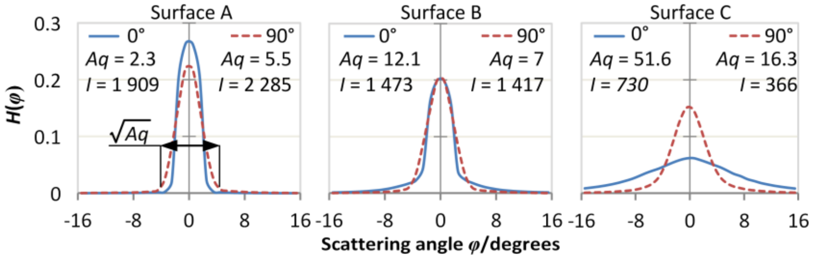


Figure 3: Normalized intensity function $H(\varphi)$ at scattering angles $\varphi$ on surfaces A, B and C at 0° (collinear) and 90° (perpendicular), *Aq*/a.u., *I*/a.u. (a.u. is arbitrary unit).

## 3 Conclusions

The effect of angular orientation of a commercial scattered light sensor on roughness measurements of cylindrical polished surfaces with crossed surface lay was investigated and quantified. Surface texture directionality, curvature and roughness level are shown simultaneously affecting the measurement, and indications on proper sensor alignment are given. For the investigated surface textures, the optimal orientation of the sensor detector is collinear to the specimen axis and to the bisector of the two dominant surface lays, regardless of the roughness levels. In this way the effect of surface curvature is suppressed and the texture properly characterized.

**Acknowledgements:**

This work was co-funded by the EC FP7 collaborative project – “IFaCOM” (Project no. NMP-FoF 285489). The authors wish to thank Miriam Gambula from the University of Naples Federico II for performing part of the measurements.

**References:**

[1] ISO 25178-6:2010 Geometrical product specifications (GPS) - Surface texture: Areal - Part 6: Classification of methods for measuring surface texture

[2] VDA 2009 Geometrische Produktspezifikation Oberflächenbeschaffenheit Winkelaufgelöste Streulichtmesstech-nik Definition, Kenngrößen und Anwendung (Frankfurt: Verband der Automobilindustrie E.V.)

[3] Seewig J, Beichert G, Brodmann R, Bodschwinna H and Wendel M 2009 Extraction of Shape and Roughness using Scattering Light *Proc. SPIE 7389, Optical Measurement Systems for Industrial Inspection VI (Munich, June 15 2009) 73890N*