

Technical University of Denmark



## Investigation of Tooling for Anisotropic Optical Functional Surfaces

Li, Dongya; Regi, Francesco; Zhang, Yang; Madsen, M. H. ; Nielsen, Jannik Boll; Tosello, Guido

*Publication date:*  
2017

*Document Version*  
Peer reviewed version

[Link back to DTU Orbit](#)

*Citation (APA):*

Li, D., Regi, F., Zhang, Y., Madsen, M. H., Nielsen, J. B., & Tosello, G. (2017). Investigation of Tooling for Anisotropic Optical Functional Surfaces. Abstract from 16th International Conference on Metrology and Properties of Engineering Surfaces (Met&Props 2017), Gothenburg, Sweden.

**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.

# Investigation of Tooling for Anisotropic Optical Functional Surfaces

D. Li<sup>1</sup>, F. Regi<sup>1</sup>, Y. Zhang<sup>1</sup>, M. H. Madsen<sup>2</sup>, J. B. Nielsen<sup>3</sup>, G. Tosello<sup>1</sup>

<sup>1</sup>Technical University of Denmark, Department of Mechanical Engineering,

<sup>2</sup>Danish National Metrology Institute, <sup>3</sup>Technical University of Denmark, Department of Applied Mathematics and Computer Sciences

**E-mail:** dongyli@mek.dtu.dk

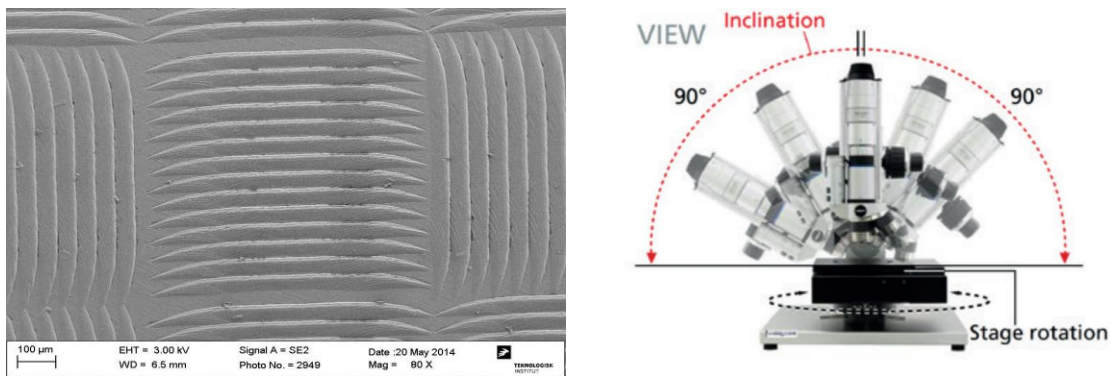
**Keywords:** anisotropic surface, surface characterization, digital microscope, design of experiment, milling process optimization, tool wear

**Abstract** This paper studied steel inserts with anisotropic surfaces for injection moulding. The inserts surfaces were machined by a five-axis micro-milling machine and the surface structures will be replicated by injection moulding. The aim of the surface structuring is to maximize visible contrast between horizontally orthogonal textured surfaces from a certain viewing angle, of both the insert and the polymer replicas. The contrast is defined by the difference of the reflectance between two areas with horizontally orthogonal textures under a certainly fixed light source. The brightness of the surface is assessed by processing the images obtained from a digital microscope Hirox RH-2000 [1]. **Error! Reference source not found.** illustrates the studied surface structure and the microscope. The optical axis of microscope can be tilted within 90 degrees from the horizontal level, which simulates the viewing angle; the analysed surface texture can be rotated horizontally by the adjusting the stage so only one surface was used to achieve orthogonal textures and images at different rotation angle can be captured. Via image processing tool, the reflectance (brightness of the obtained images) will be analysed and therefore the contrast can be calculated.

A full factorial 2-level design of experiment (DOE) with 5 factors was used to evaluate the influence of milling parameters including: spindle speed, feed speed, cooling condition, tool diameters and orientation of textures [2]. The orientation of textures was considered as the accuracy of the milling machine along x and y axis might result in different finish of the anisotropic featured surface. **Figure 1.** Left: The surface microstructure investigated in the paper; Right: The Hirox RH-2000 digital microscope.

**Table 1** lists the setup for each parameters. The roughness and the dimension of the surface were measured by a laser confocal 3D scanner. The measurement uncertainty is calculated. The roughness of the surface and the contrast obtained by rotating the surface were used as the response of the DOE. Eventually, the micro-milling process was optimized.

Moreover, based on the optimal milling process parameters, the tool wear was investigated by inspection to the geometry and the achieved contrast of the obtained surface structures. Areas of 0.8mm x 0.8mm with the studied structures will be milled by the optimized process parameters. Every 100<sup>th</sup> area were measured. The obtained dimensions of the structures and the contrast were plotted against the area number so that the influence of the tool wear on the geometry and the function was revealed.



**Figure 1.** Left: The surface microstructure investigated in the paper; Right: The Hirox RH-2000 digital microscope.

**Table 1.** The investigated milling parameters and levels in the DOE.

Factor	Cutter	Spindle speed	Cooling	Feed speed	Orientation
Low	Φ3mm	8500rpm	oil+air	700mm/min	Horizontal
High	Φ4mm	9600rpm	oil+water	1000mm/min	Vertical

**References:**

- [1] Nevas, S., Manoocheri, F., & Ikonen, E. (2004). J. Gonioreflectometer for measuring spectral diffuse reflectance. *Applied Optics*, 43(35), 6391–9.
- [2] Douglas C. M. (2012). *P. Design and Analysis of Experiments*, 8th Edition, New York, (Wiley Global Education), 320-393.