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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

European Society for Precision Engineering
and Nanotechnology (euspen),
18th International Conference,
Venice (Italy), 4th – 8th June 2018

Pitch measurements validation of steel inserts micro-grooves with light diffractive properties using a Laser Scanning Confocal Microscope (LSCM) and an Atomic Force Microscope (AFM)

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Abstract

The optical principle of structural colouration provides to a surface unnatural and iridescent colouring properties. Surface topography combined with lighting characteristics are the physical driver of the phenomenon. Structural colouring arises from the presence on the specimen of nanoscale features distanced by a length comparable to the near visible light spectrum (300-1000 nm). The micro structures behave as a band-pass filter for certain light wavelengths, enabling an unnatural colouring effect. Elliptical Vibration Texturing (EVT) is an on development technology for fast texturing of gratings on metal inserts for structural colouration purposes.
To identify the accuracy of EVT, in this study, two different microscopes assess an EVT grating with a 1000 nm nominal pitch on a steel flat surface.
On first, optical-based metrology is selected adopting a Laser Scanning Confocal Microscope (SCM) with a 405 nm blue source to tackle the measuring purpose. Secondly, an Atomic Force Microscope (AFM) in Intermittent contact mode (IC-AFM) is adopted. Considering the differences in set-up time and scanning range, the objective of this research is to identify the most favourable measuring technique.
On the sample images, five average profiles on different locations provide consistent information about the process repeatability. Pitch estimation comes by means of FFT algorithm on the extracted profiles. The average result for SCM measures is 1002 ± 31 nm while for AFM is 972 ± 15 nm. At last, from these results, the estimation of EVT accuracy is presented.

Scanning Confocal Microscopy, Dynamic Force Microscopy, Elliptical Vibration Texturing, Structural Colouration

Elliptical Vibration Texturing (EVT)

• Objective ⇒ Texture bio-inspired structural colours [1].
• Task ⇒ Generate a periodic grating with a nominal pitch of 1000 nm [2].

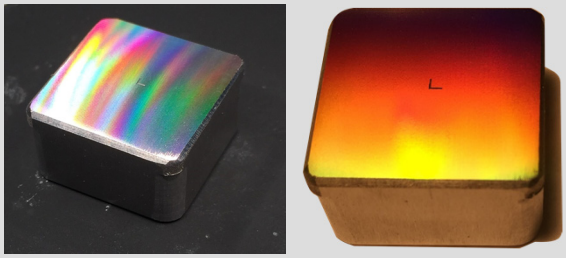

Fig. 1: 20 mm x 20 mm x 10 mm steel insert with light diffractive properties [3]

Metrology

• Objective ⇒ Compare Scanning Confocal Microscopy (SCM) and Atomic Force Microscopy (AFM)
• Task ⇒ Evaluate pitch of the periodic grating.
• Procedure ⇒ 1. Cut FOV to 80 x 80 µm².
2. Resize to 4096 x 256 pixels².
3. Levelling with Least Square plane.
4. Pitch estimation with FFT.
5. Uncertainty calculated with GUM [4,5].

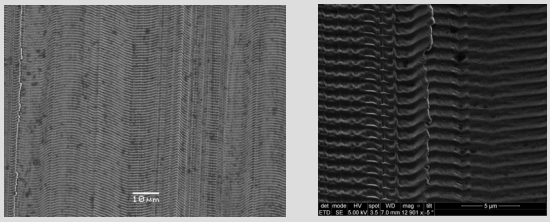

Fig. 2: Different magnification of the grating surface by means of SEM

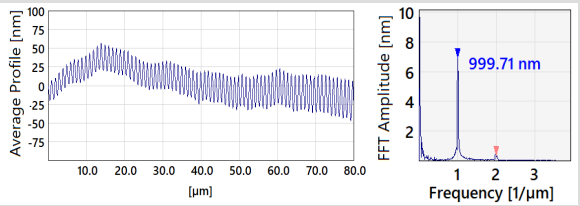

Fig. 3: Average profile (left) and dominant pitch estimation (right)

Conclusion

In this study, two measuring strategies undertake the challenge of measuring 1000 nm nominal pitch gratings of a structural coloured steel insert. SCM shows a consistent result with AFM used in Dynamic Force Microscopy setting. The expanded uncertainty calculated for SCM is almost twice as large than the AFM one, due to calibration and physical principal. However, measuring time is significantly smaller for SCM than AFM. A final consideration from this study provides EVT average process accuracy to the below 30 nm range.

Scanning Confocal Microscopy

High magnification objective (50x)	
Working Distance (WD)	350 µm
Numerical Aperture (NA)	0.95
Field of View (FoV)	259 x 259 µm²
Repeated measurements	10
Image resolution	4096 x 4096 pixels²
Pixel sixe	63 nm
Set-up time	15 min
Measurement time	5 min

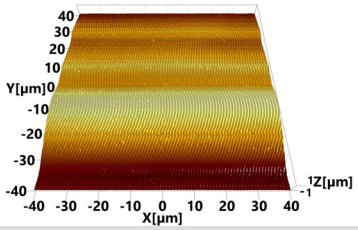

Fig. 4: Image Sampled with SCM

Atomic Force Microscope

Intermittent contact mode (IC-AFM)	
Vertical oscillation Amplitude	20 nm
Horizontal scanning speed	8 µm/s
Scanning area	80 x 80 µm²
Repeated measurements	5
Image resolution	4096 x 256 pixels²
Pixel sixe	20 x 313 nm
Set-up time	60 min
Measurement time	43 min

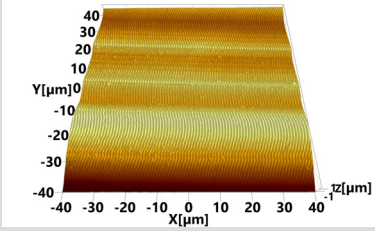

Fig. 5: Image sampled with AFM

Measurements results and comparison

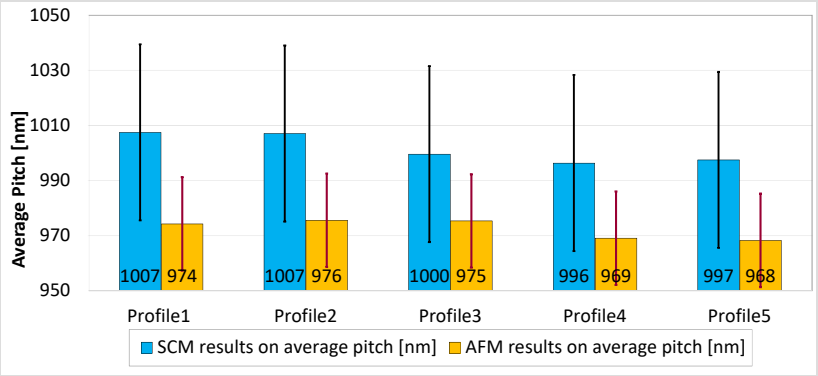

Fig. 5: Average and uncertainty of pitch estimation calculated on the SCM (a) and AFM (b)

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 767589. PROSURF ("Surface Specifications and Process Chains for Functional Surfaces"). This project has received funding from the Danish Innovation Fund (https://innovationsfonden.dk/en), in the research project of MADE DIGITAL, Manufacturing Academy of Denmark (http://en.made.dk/), Work Package WP3 "Digital manufacturing processes". The work has been supported by funds from the Danish Agency for Institutions and Educational Grants.

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