BIPM Capacity Building & Knowledge Transfer Programme

FUTURE NEEDS FOR METROLOGY Summer School and METAS Project Placement

REPORT

Project Name	Surface Texture Metrology by Profile Methods: A Comprehensive Study of Measurement and Analysis Techniques
Description	This project aims to understand the fundamental principles, standards used, calibration procedures, data collection and analysis, as well as the evaluation of the uncertainty budget in surface texture metrology by profile methods.
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Motivation & Introduction

The proposed project addresses the critical need for accurate and consistent surface texture measurements, particularly through profile methods, which are fundamental in industries such as manufacturing, engineering, and material science. Surface texture significantly impacts product performance, durability, and quality, making precise measurement essential for quality control and standardization. The challenges faced by the metrology community often arise from varying measurement techniques, calibration complexities, and the influence of filters on data accuracy. This project aims to bridge these gaps by providing a deep understanding of ISO standards, calibration procedures, and data interpretation. The primary objective is to equip metrology professionals with the knowledge and skills necessary to improve measurement accuracy and manage uncertainty effectively, ultimately enhancing the precision of surface texture evaluations and supporting the standardization efforts in the field.

Research

The research for this project was conducted in two stages: a theoretical study and practical laboratory work. For the theoretical study, I focused on understanding the fundamental concepts and ISO standards governing surface texture metrology, specifically ISO 3274, ISO 4287, ISO 4288, ISO 5436, ISO 12179, and the newly updated standard ISO 21920-2 & 3. These standards define surface texture measurement techniques, parameter definitions, and calibration procedures. I explored essential surface texture parameters such as Ra, Rq, Rz, Rt, etc., which are used to characterize surface roughness and overall quality. I also studied various filtering methods, including Gaussian and Robust filtering, to separate roughness and waviness profiles based on the cutoff values λs, λc, and λf, which are critical for accurate surface texture measurements. Additionally, I learned about contact and non-contact measuring techniques, particularly optical profilometry, and understood its advantages and limitations.

In addition, I learned that the measuring instruments need to be calibrated based on some parameters such as geometric static calibration (using spheres artefact, optical flats, and glass scales), dynamic calibration (using piezoelectric devices), and force calibration (using force scales). This knowledge allowed me to understand how to develop the uncertainty budget for each type of standard used in surface texture measurement. Specifically, I focused on depth standards (Type A), spacing standards (Type C), and roughness standards (Type D), ensuring reliable and accurate measurements. This theoretical study laid the groundwork for the practical application of these concepts during laboratory work.

During my laboratory work, I had the opportunity to experience the practical daily tasks of surface texture calibration at METAS using the MarSurf LD 130 instrument, with the stylus tip probe. I learned about the step-by-step calibration procedure, starting with checking the specimen using a microscope, cleaning the specimen, selecting the appropriate tip and filter for calibration, performing the daily calibration for the instrument, choosing measuring script based on measuring plan, aligning the specimen on the instrument fixture, collecting and analyzing data, and drafting the certificate before uploading it to the METAS ERP system.

Some of my findings during the practical laboratory work are as follows:

1. Cutoff Filter Selection: The correct choice of a cutoff filter (λc) is essential and must follow a clear hierarchy: the specifications on the standards, the most recent calibration data, the customer's requirements, and finally, the guidance from ISO 21920-3. This hierarchical approach ensures that the correct filter is chosen for accurate measurements.
2. Daily Instrument Calibration: The instrument calibration is crucial for reliable performance. It must be performed daily or by any probe change, using the instrument's software and its reference sphere. It is from good practice to then verify this calibration using a previously defined script, we evaluate the radius of another sphere artefact using a circular fit method. The radius is then compared to previous data, with a tolerance of less than 300 nm.
3. Additional Instrument Verification: Periodical additional instrument verification is also necessary to verify its performance in three stages: force calibration (using weight references), probe tip shape verification (no wear facet) by looking at the probe tip under a microscope or by a geometry calibration (using a sphere artefact), verification of the instrument noise and straightness on the X axis (presence of dust) by measuring a polished surface.
4. Automated Data Analysis: The data analysis and creation of the calibration certificate are mostly automated through LabView software developed by METAS. After inputting the analysis parameters (e.g. cutoff filter, standard type), the software generates the measurement data along with its uncertainty, which can be automatically exported to a calibration certificate. However, for measuring parameters outside the scope of ISO 5436 and ISO 21920-2 require manual analysis to define the profile section.

In this context, reflecting on one of the key aspects emphasized during the "FUTURE NEEDS FOR METROLOGY" Varenna Summer School, the advancements in metrology automation directly aligned with my experience at METAS. I learned how the integration of digital technologies, such as LabView software for automated data analysis and calibration certificate drafting, can significantly enhance the efficiency and accuracy of surface texture measurements.

Figure 1. Surface Texture Measuring Setup at METAS

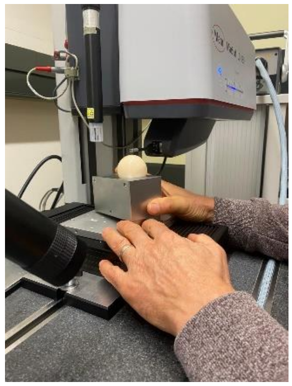

Figure 2. Measuring Instrument Calibration using Sphere Artefact

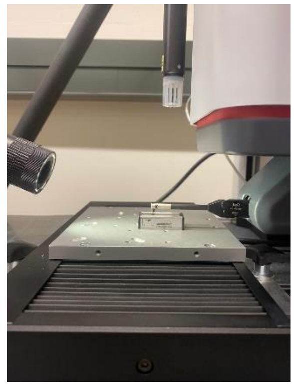

Figure 3. Roughness Standard Type D Calibration

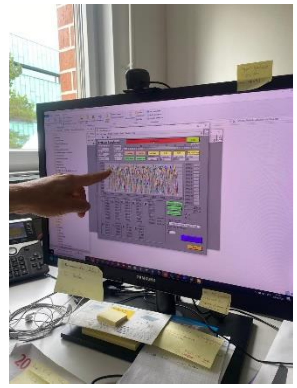

Figure 4. Data Analysis using LabView Software

Conclusions and Future Work

This project successfully achieved its primary objectives of enhancing knowledge and skills in surface texture metrology, focusing on ISO standards, calibration procedures, and uncertainty management. Through both theoretical study and hands-on experience at METAS, I gained a deep understanding of essential surface texture parameters, filtering methods, and the significance of proper calibration for reliable measurements.

For future work, I plan to enhance the reliability of measurements at my National Metrology Institute (SNSU BSN) by refining the calibration procedures of measuring instruments and evaluating the uncertainty budget, comparing it with METAS standards. Additionally, I aim to develop an automation system that will further improve measurement efficiency and accuracy, supporting better quality control and standardization in the field.

Acknowledgements

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