AN ANALYSIS OF THE METROLOGY TECHNIQUES TO IMPROVE QUALITY AND ACCURACY

***Numan M. Durakbasa*[1]*, Gökcen Bas*[2]**
[1]*Prof.Dr., Vienna University of Technology, AuM, numan.durakbasa@tuwien.ac.at*
[2]*Dr.techn., Vienna University of Technology, AuM, goekcen.bas@tuwien.ac.at*

ABSTRACT

Today's continuous sophistication of products requires quality control and quality assurance to ensure specifications and relevant norm compliance. The objective of quality control is eliminating errors and integrating continuous improvement in the processes by means of accurate measurement devices. However, every quantitative indication of the quality has a level of uncertainty based on the measurement techniques. Therefore, ideal measurement is defined with standards and guidelines for more precise and accurate measurement and evaluation.

This study focuses on high precision metrology techniques that have been an indispensible part of the advanced production industry. The parameters affecting the uncertainty of the measurements are defined and experimental measurements are carried out to develop procedures in order to improve the accuracy of the measurements.

Keywords: quality, accuracy, high precision, micro-/nanometrology

1. INTRODUCTION

The changes in the manufacturing industry with intensified high quality and complex product realization face new challenges. To overcome these challenges, there is a strong need for precise production metrology, which enable measurable quality criteria of the products.

Today, the general principles of quality management with various efficient tool, methods and techniques are introduced to offer the manufacturing industry efficient and low cost operation. Quality management systems in compliance with the international standards of the ISO 9000 series provide the guideline for establishing an integrated management system that solves the organizational challenges of efficiency and quality [1,2].

At the same time, the products of the next generation manufacturing with significant complexity of geometry and material require tighter tolerances and quality specifications, which put an increasing importance of modern precision metrology applications. Thus, high precision metrology has become of high priority at the implementation of crucial requirements for quality of products [3].

As the technological needs for functionality of a workpiece has changed with developing manufacturing industry, the measurements and assessment of the workpieces based on form and position tolerances have become increasingly important [4]. Besides, the problem of workpiece accuracy based on form and

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position tolerances has been widely discussed and studied at several studies [5, 6, 7, 8].

A set of requirements concerning the workpiece accuracy and requirements of form, size, dimension and tolerances is known as the "Geometrical Product Specification and Verification (GPS)" [9]. The concept of measurements and their evaluation with regard to GPS can be carried out by both optical and contact mode metrology techniques. Different methods offer their limitations, advantages and accuracy. This study focuses on a measurement of both optical and contact mode measurement procedures aiming to highlight the importance of high accuracy measurements with reduced uncertainty.

2. INFLUENCE PARAMETERS IN PRECISION MEASUREMENTS

It's becoming indispensible part of the manufacturer operations to provide the technical means, tools and methods to ensure the quality criteria and product specifications. This practice aims to enable consistency in the product quality by avoiding high costs and inefficient applications. Geometrical product specifications are a means to transform function dependent demands into produced workpieces and parts based on [10]:

- mathematical rules and methods,
- consideration of macro and micro geometry,
- possibilities for measuring of quantities and particularly tolerance quantities and,
- evaluation of uncertainty.

In the mechanical parts of manufacturing, there exist deviations of location and orientation because of the interactions between the different features forming the periphery. The geometrical shape of the machined parts is usually more complex and comprises various features. Hence, not only is keeping the proper dimensions of the workpieces but also proper orientation and location of individual elements become necessity. Due to manufacturing circumstances, it's not easy to achieve these features. To set the permissible limits of common location and orientation of the elements the orientation, location and run-out tolerances are defined. The geometrical tolerances limit both deviation and the real form of a workpiece as well as its orientation and location. There are three kinds of tolerances related to the orientation and location to be distinguished [11]:

- orientation tolerances,
- location tolerances, and
- run-out tolerances.

To fulfil the workpiece tolerances and surface finishes, it is necessary to incorporate the high precision metrology into the manufacturing processes. During the measurements, it's essential to identify the parameters that are possible sources of uncertainties in order to improve the accuracy and precision. Hence, a practical list of the measurement uncertainty sources is available, including examples such as incomplete definition of the measurand, sampling, matrix effects and interferences, environmental conditions, uncertainties of masses and volumetric equipment, reference values, approximations and assumptions incorporated in the measurement method and procedure, random variation and besides appropriately qualified staff, proper maintenance and calibration of equipment and reagents, use of appropriate reference standards, documented measurement procedures and use of appropriate check standards and control charts [12].

However, to meet the commercial and industrial applications, it's common that a device is tested through a comparison with a measurement standard and the uncertainties associated with the standard and the comparison procedure are negligible relative to the required accuracy of the test. For the well-characterized measurements, the best available estimate of the expectation or expected value of a quantity q that varies randomly and for which n independent observations q_k have been obtained under the same conditions of measurement is the arithmetic mean or average $\bar{q}$ of the n observations as represented in the Formula 1 [13]:

$$\bar{q} = \frac{1}{n}\sum_{k=1}^{n} q_k \qquad (1)$$

The experimental variance of the observations, which estimates the variance σ^2 of the probability distribution of q, is given by the Formula 2 [13]:

$$s(q_k) = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(q_j - \bar{q})^2} \qquad (2)$$

The experimental standard uncertainty u, associated with the average for n reading is associated with the Formula 3:

$$u = \frac{s(q_k)}{\sqrt{n}} \qquad (3)$$

The metrological analyses play a primary role in the quality management system of the production industry. In order to assure high quality expectations in the next generation manufacturing technology, the causes of measurement errors can be analysed by a cause and effect diagram (Ishikawa diagram) as represented in the Fig.1.

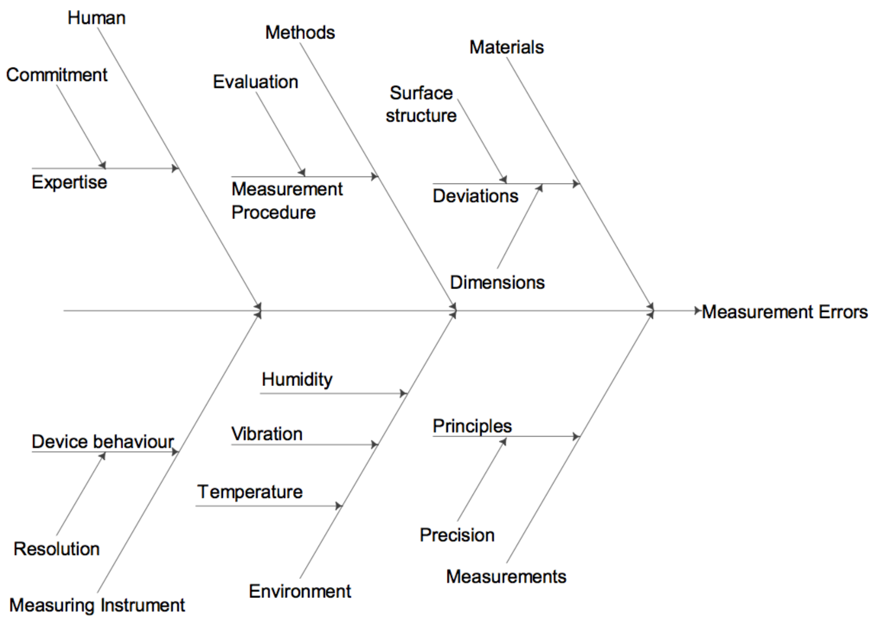

Fig.1 The cause and effect diagram of the measurement errors

3. METROLOGICAL APPLICATIONS

The science of high precision metrology is an indispensible part of the scientific research as well as industrial applications. However, to meet the requirements of high precision metrology, high accuracy in the sub micrometer and nanometer range is mandatory for international recognition of the results under guidance of the international standards. Only the conveniently designed laboratory with consistent and reproducible environmental conditions may ensure measurements with high accuracy fulfilling the tasks with the smallest measurement uncertainties.

The most important environmental measurement influences are:

- temperature (thermal conduction, convection and radiation)
- vibrations
- humidity
- pollution

The structural organization of a precision measurement room ensures that these disturbing influences are reduced and kept constant. The High precision measurement room – Nanometrology Laboratory of the Vienna University of Technology demonstrates the features for such a building and technical realization.

The measurements carried out at the laboratory provide both contact mode and optical analysis of the workpieces. The modern metrology instruments offer performance specifications that allow working in compliant with the corresponding standards.

The technical specifications of a 3D Digital Microscope is presented in this study as Table.1 to establish an example of optical measurement application [14].

Table.1 The technical specification of a a 3D Digital Microscope

Specifications			
CCD	1/1.8″ image sensor		
Resolution	1200x1600		
Magnification on a 21.5″ monitor	200x	1000x	2000x
Horizontal Observation range(µm)	1220	310	120
Working distance(mm)	10	10	10
Vertical resolution(nm)	50		
Repeatability(µm)	0,5		

An industrial cutting tool geometry and surface topography is measured and analysed according to the standards of ISO 25178 series [15, 16]. The surface measurement resulted the surface roughness values of R_a = 0,229 µm and R_z=1,207 µm on a profile of 26,671 µm x27,598 µm as represented in the Fig.2. The tool geometry on the cutting edge surfaces is represented in the Fig.3.

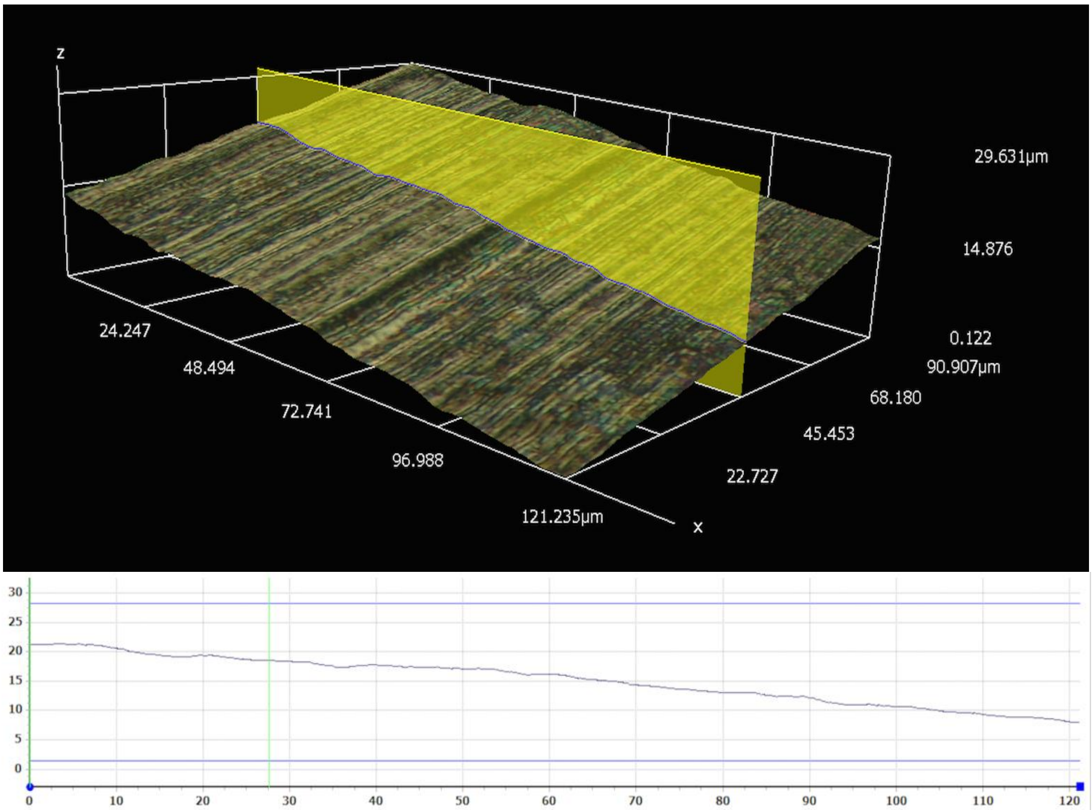

Fig.2 Surface profile of an industrial cutting-tool measured by a digital microscope

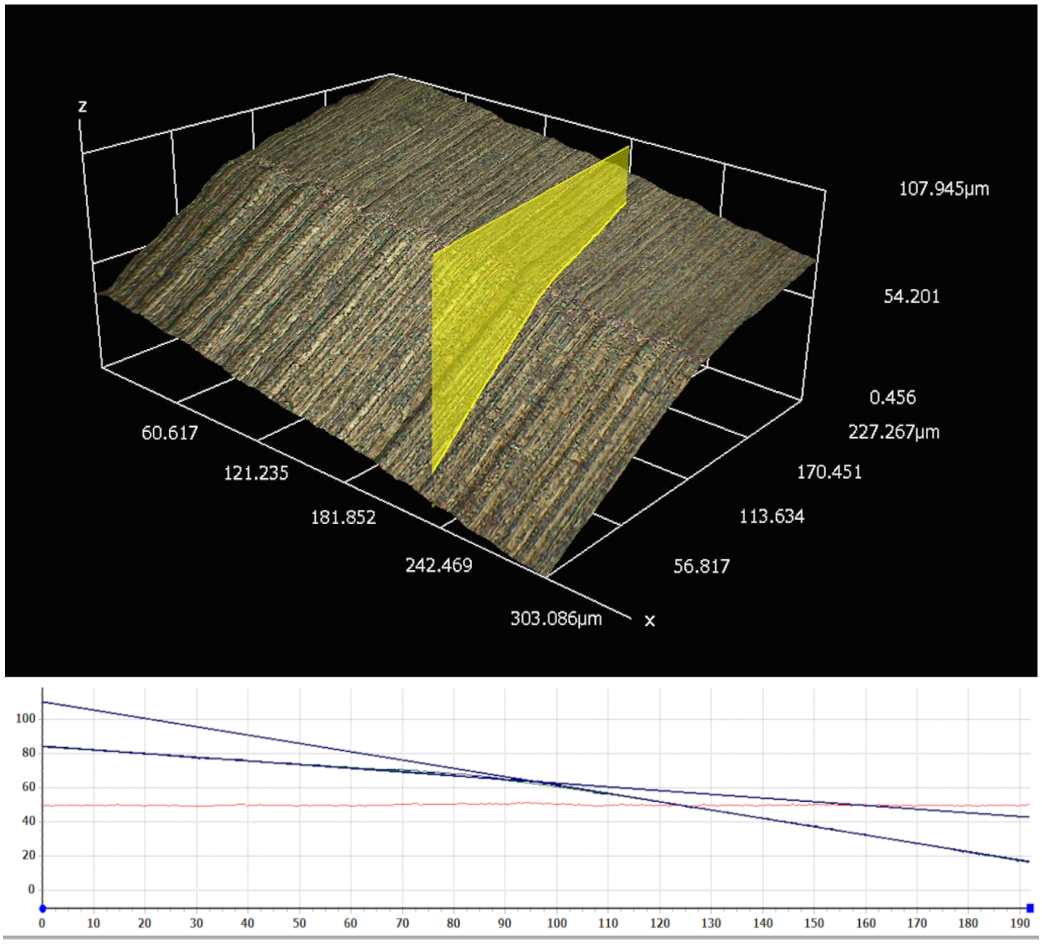

Fig.3 Cutting tool edge geometry measured by a digital microscope

4. CONCLUSION AND FUTURE WORK

The developments in the manufacturing industry bring the challenges of next generation technology challenges of product quality control and quality assurance. The solution to overcome these challenges lays in the modern metrological applications. However, real world disturbances and other influence factors shall be defined and regarded as uncertainty factors while carrying out measurements.

This study gives an overview of the uncertainty influences to summarize the basic requirements of a quality control and assessment measurement. Moreover, a high precision measurement is implemented under controlled environment and defined specifications in compliant with the corresponding standards to give an example of an industrial workpiece assessment.

The developments of the metrology instruments enable to accommodate measurements of higher precision and accuracy in the near future. The next generation manufacturing industry challenges will depend on more correlated studies in order to establish more efficient and low cost solutions.

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