TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 59, Issue IV, November, 2016

# THE ACCURACY AND REPRODUCIBILITY OF MEASURING SENSORS ON WORK PIECES WITH VARYING PROPERTIES

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***Abstract:*** *This article is intended to show the essential today basic principles and the actual status of the accuracy and reproducibility of measuring sensors on work pieces in the industrial manufacturing metrology.*
***Key words:*** *quality assurance, production measurement technology, measurement deviation, industrial work piece properties.*

## 1. INTRODUCTION

In the field of mechanical engineering, whether a work piece fulfills its function and is a quality product depends to approximately 80 percent on its geometrical measurements. The determination of these measurements and the safeguarding that the same measurements, determined in different places via varying methods, substantiate exactly the same statement, are to be ascertained in production measurement technology [1].

In any mechanical manufacturing, measuring is the essential prerequisite for successful production control.

Production measurement technology mainly affects the geometrical sizes of work pieces. Thereby, production measurement technology is not only found in classic technical core sectors such as mechanical engineering, automotive engineering and the aviation industry, but anywhere, where geometrical features have to be verified.

On the one hand, production measurement technology can be closely linked to production or even integrated into production processes. On the other hand, it also proceeds in precision measurement rooms, secluded from production, for example for the research and development of processes and products and for inspection equipment monitoring [2].

## 2. APPROPRIATE SELECTION OF SENSORS FOR IMPROVED QUALITY

A complete measurement can be obtained through different measuring sensors. Though, whether these are acceptable for the pending measuring task is decided by several factors, which have to be analyzed. Today's measuring instrument users are increasingly confronted with the question of which measuring instruments are suitable for the validation of different tolerances on work pieces [3].

Not least, increasing demands for systematic test planning call for precise decision rules. Here, the applications and criteria, which are regulated in the respective standards, and the allowed tolerances for the test tasks are of great importance. Even a divergence of a few hundredth millimeters can compromise a work piece's function. If a test task is carried out via different measuring sensors, the results are difficult to compare and therefore not reproducible. Requirements for the measuring instruments are very high in terms of precision and speed, as the work pieces and tolerances become more delicate.

Nevertheless, the application of measuring sensors solves complex measuring tasks precisely, flexible and with a high level of automation. Despite these advantages there are still problems. Thus the application of different measuring sensors for an identical test task

yields varied results. Figure 1 shows an easy and introductory example.

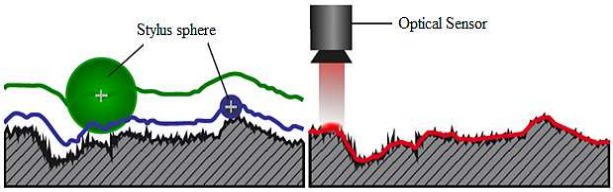



**Fig. 1.** Different sensors acquire various surfaces [4]

It becomes apparent that with a complex surface geometry, different filter effects occur simply through filter selection.
So far there is no suitable selection of an appropriate strategy. It is determined through the user.

### 2.1 Accuracy Specifications for safe Production

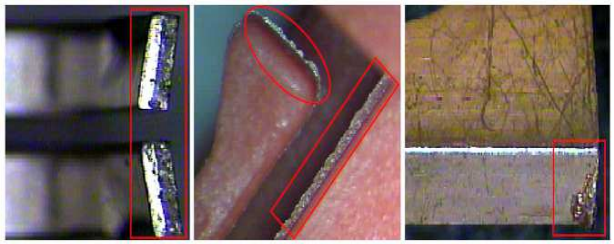
Besides the strategy for the selection of the preferable sensor, the significance of precision increases considerably. Knowledge of accuracy is of vital importance for the evaluation of measurement results and for validation assertions.
"Problems increase, because today companies produce globally in close cooperation with their suppliers. Identical measuring tasks are to be solved at different company and supplier locations [3]."
According to the quoted source, the difficulty of working with a cooperation partner and developing a high-quality product lies mainly therein that both are equipped with divergent technology and varying know-how.
Crucial is a quality management based upon precise and reproducible test results. Therefore a consistent system, which safeguards identical measuring procedures and determined measurement accuracy in different places, has to be developed.

### 2.2 Incorrect or Omitted Measuring can cost a lot of Money

Should, for example, measured dimensional specifications be incorrect, the manufacturing department is forced to reset their machine tools, even if an error occurred during production measurement technology. In the end they cannot conjecture the problem here. In today's technologically advanced time, there are miscellaneous, highly accurate sensors. However, even different measuring procedures with differently applied sensors yield varying measurement results, which are afflicted with an undefined accuracy. Therefore it is very important to make an assertion on the individual accuracy hereafter, so that the development/construction department can constrict the specified drawing tolerance in relation to uncertainties.

## 3. WORK PIECE PROPERTIES LEAD TO COMPLEX METROLOGICAL REQUIREMENTS

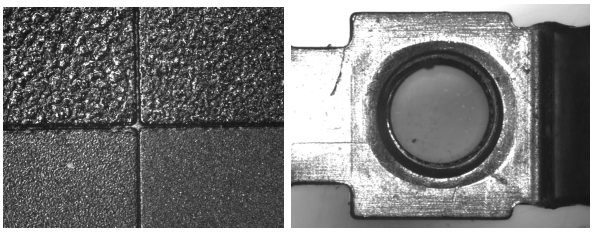
Since work pieces are designated with varying properties, there are (depending on the setting of the parameters to be measured) distinct deviations.
This concerns, among other things, the measuring object's form deviation with the consequence that the points sampled in the measurement are not representative.
Flash plays a considerable role with synthetic work pieces and burr with metallic work pieces. Figure 2 visualizes typical faults of work pieces, which cause measurement deviations.



a) b) c)

**Fig. 2.** Typical work piece deviations
a) Form deviation, b) Flashing, c) Manufacturing ridge

Optical properties, such as reflection methods, influence the measurement result when optical measuring instruments are deployed. Surface finish plays an essential role in the implementation of tactile measuring principles.
Properties caused by the surfaces are classical bias. Measuring sensors operate differently since generated contrast and shadow features and shiny patches have different effect.
Figure 3 exemplifies typical work piece properties, which can evoke bias.



a) b)

**Fig. 3.** Work piece properties in the industries
a) Different roughness, b) Shining areas and shadow features

Another bias, not retrieved by surface finish, are “deviations of synthetic materials”, which are caused by moisture absorption.
Dimensional detection in synthetic work pieces according to drawing specification occurs within 24 hours. In accordance with din 16742, measuring the work piece immediately after it exits the machine is not advisable, since synthetic parts acclimatize shortly (one to two hours) in production [5].
Since water absorption is dependent on environment conditions and season, it is referred to as measuring in undefined condition. Depending on environment conditions and season, specific work pieces grow up to 0,2 mm within two to four weeks. Until today, there are no comprehensible findings on polyamide (PA) as well as work pieces with different proportionally reinforced fiber optics. Work pieces grow substantially and deform.
Therefore length variation ΔL is an important examinable parameter for accuracy specifications of measurement results. A visualization of length variation is demonstrated in figure 4.

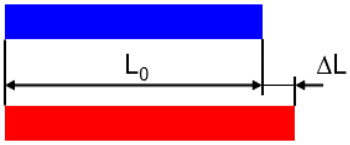



**Fig. 4.** Visualization of length variation [6]

## 4. CONCLUSION

### 4.1 German Industry Research in Cooperation with the Technical University of Cluj-Napoca

Considered experimentally assertions are made on the accuracy of individual sensors in cooperation with the Technical University of Cluj-Napoca (the German-speaking study programme).
Moreover, a distinct reproducibility of real work pieces is examined with different sensors. To this end, a measurement uncertainty consideration is conducted statistically through a variety of different sensor measurements.
The calculations are deemed exceptional, since particularly optical sensors have not been scrutinized to such an extent.
Furthermore, accuracy considerations of real work pieces are seldom approached in industries, since knowledge in this mathematical field is not lived. Companies such as Bosch, Daimler Chrysler, General Motors, Volkswagen et al. have their own guidelines, yet only properties in accordance with MSA (Measuring System Analysis) are assessed. The objective of MSA is to expose the ability of measurement and verification processes.
Individual and substantially systematic influences are not considered herein. Common influences are depicted exemplarily in figure 5.

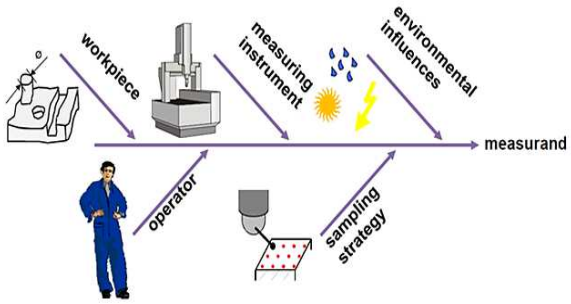



**Fig. 5.** Causes for measurement deviation, Ichikawa-Diagram [7]

The well-known Ichikawa-Diagram is meant to assist and inspire the determination of individual influences and help with the ascertainment of influencing factors.
Among others, the influence of the work piece, which can for example originate through moisture absorption (see figure 4), is withdrawable. How thoroughly the respective work piece changes, has to be examined, since there are only estimated values in this area. Polyamide is regarded as an important synthetic work piece in the industry, since it is indispensable due to its low costs and chemical properties. Furthermore, it is crucial to examine work pieces of different color.

Currently it is merely evident that different sensors have varying effects on the examination of different work piece colors. Therefore, only recommendations on the settings for parameters to be measured are made. Which extent they will have as uncertainty contribution, remains a research question. By compliance with several parameters that are difficult to adhere to, such as moisture regulation, temperature compliance, vibration protection et al., it is possible to determine referenced values via calibrated normals (reference pieces) in an industrial measuring laboratory. Thus, it is possible to identify individual influences and rough uncertainties step by step through a series measurement [8]. Furthermore, certain measurement ranges can be simulated with the available three-dimensional measurement technology, in order to eliminate their systematic influence in advance.

### 4.2 Further investigations

Another area of research is the examination of the coherent understanding that one and the same language is spoken (especially in the European area) when it comes to drawing interpretation and measuring. Here, it is also revealed which rough uncertainties may originate from technical two-dimensional drawings and how these can be optimized through consideration of work piece properties.
Technical two-dimensional drawings are still not produced sufficiently by the construction and development department, potentially resulting in different assertions for a single measurement procedure. In the end, the departments for construction, development and production measurement technology have to be synchronized precisely.
International standards were introduced for this purpose, such as din en iso 14405, din en iso 5459 or din en iso 8015.
These change annually since progress advances.
The problem here is that the departments (construction, development and production measurement technology) are falling behind. Therefore it is very important to seek out the essential international (en iso) standards and to analyze them practice-oriented and precisely. In doing so, a standard or guideline is developed, which shall minimize uncertainties.

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**Precizia și reproductibilitatea senzorilor de măsurare pe piesele în lucru cu proprietăți variabile**

***Rezumat:*** *Acest articol este destinat să arate principiile de bază esențiale din ziua de azi și starea reală a preciziei, reproductibilitatea măsurării senzorilor asupra pieselor în lucru în metrologia de fabricație industrială.*

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