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CHALLENGES AND TRENDS IN MANUFACTURING METROLOGY – VDI/VDE ROADMAP

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ABSTRACT

‘Faster, safer, more accurately and more flexibly’ is the title of the 'Manufacturing metrology roadmap' [1, 2] issued by the VDI/VDE (The Association of German Engineers and Association for Electrical, Electronic & Information Technologies) Society for Measurement and Automatic Control published in 2011. The document presents a view of the development of metrology for industrial production until 2020 and was drawn up by a German group of experts from research and industry. 3 years after the publication the expert team meets again for reviewing the roadmap and decides to update it. The paper summarizes the content of the roadmap and the planned update.

Index Terms **–** Manufacturing Metrology, Future Trends

1. INTRODUCTION

Under the impact of global megatrends manufacturing technology is faced with a number of different challenges. The topics of resource efficiency, of mastering new process technologies, of increasing flexibility and of transparency have a special importance in manufacturing today (Figure 1). These topics are not changed significantly within the last years. Therefore the roadmap update considers the same trends as the original roadmap.

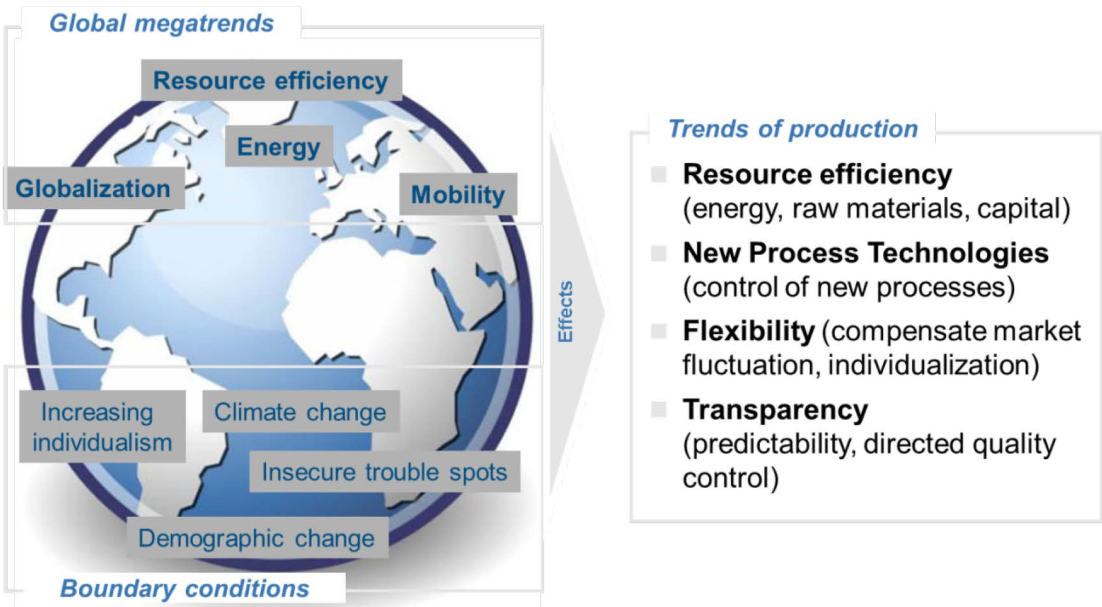

Figure 1: Global megatrends and trends in manufacturing technology [2]

Nevertheless new slogans appear to describe changes in manufacturing technology. The most important one especially in Germany is “Industry 4.0”. It is a project of the high-tech strategy of the German government, which promotes the computerization of traditional industries such as manufacturing [3]. Its impact on manufacturing metrology was already a topic of a few publications [4, 5]. Information from metrology will be transferred and presented differently. The availability of metrological information within digital networks may increase transparency of manufacturing processes. But the computerized availability requires appropriated techniques to present and process the information data. Metrology itself will not be influenced directly. Therefore the topic “Industry 4.0” is not treated separately. It is mentioned within the different sections of the roadmap in case a reference to Industry 4.0 exists.

The challenges and trends in manufacturing metrology caused by trends in manufacturing are described with the terms ‘fast’, ‘accurate’, ‘safe’ and ‘flexible’ in the original roadmap [1, 2]. Additionally holistic techniques like computer tomography and three-dimensional optical methods become more important and justify a separate term (Figure 2). The following section describe the different term of the roadmap by means of several examples.

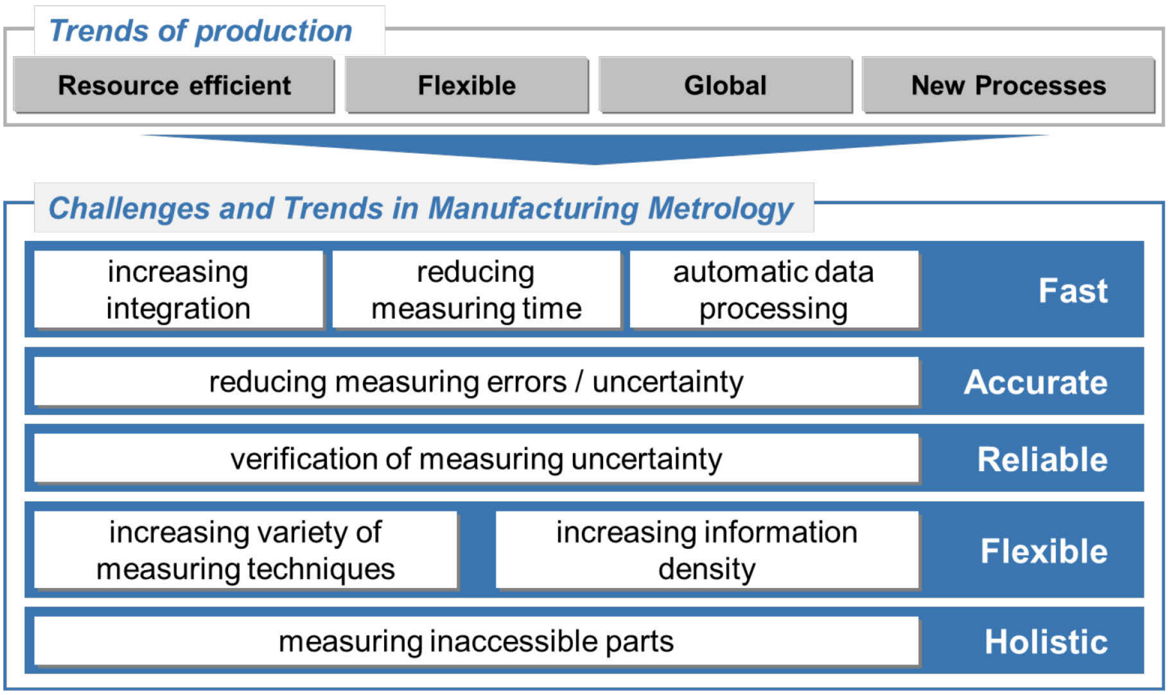

Figure 2: Manufacturing trends and their impact on challenges and trends in manufacturing metrology.

2. FAST

On one hand, speed means the development and application of metrological procedures that allow faster access to information about product quality. Here it is less a matter of developing procedures from scratch than of adapting a large number of known measurement principles for utilization in production. Optical methods play a significant role here [6] (Figure 3).

On the other hand, a tighter integration of metrology into production processes, especially by means of automation, will facilitate a faster delivery of measurement results as well as a more efficient use of measurement data.[7]. This integrative approach reduces or even eliminates the time required for product to be transported to the measuring equipment (Figure 5). Furthermore, the information from measurements is directly available in production, thereby allowing for the incorporation of control loops, for example. Regulation by means of an automated transmission of data can be implemented with a particularly high level of efficiency [8]. These developments profit from the computerization of manufacturing as the main topic of “Industry 4.0”.

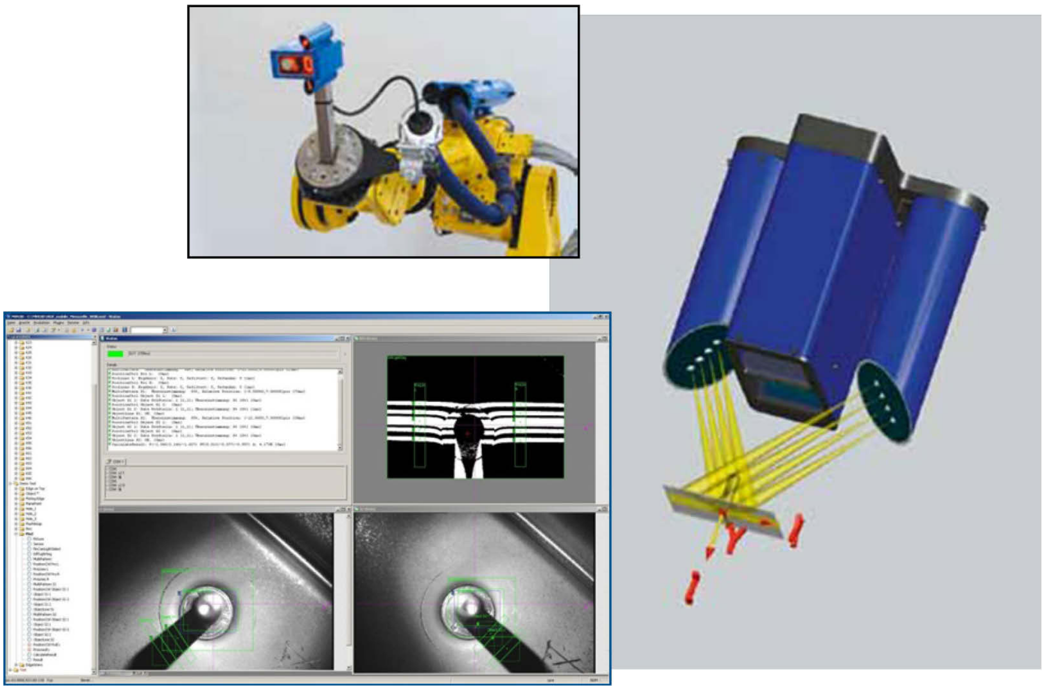

Figure 3: Example for faster metrology by optical capture of position tolerances for bolts during inspection of automotive bodywork with optical sensor on robots.

Figure 4: Example for faster metrology due to the automated integration of a coordinate measuring machine into material flow by robot loading.

3. ACCURATE

Demands relating to the accuracy of measurement technology are also increasing in conjunction with stricter quality requirements. The correct term for the quantification of accuracy is according to the ISO standards “measuring uncertainty” [10]. The technical development of the expected uncertainty in manufacturing metrology is presented in the Science and Technology Roadmaps for Metrology of EURAMET (European Association of National Metrology Institutes) [11]. All application areas of metrology show a trend to lower measuring uncertainty.

Looking on dimensional metrology for manufacturing. this trend affects not only procedures in macrometrology [12] but also the micro- and nanometrology used for capturing product shape [13] (Figure 5).

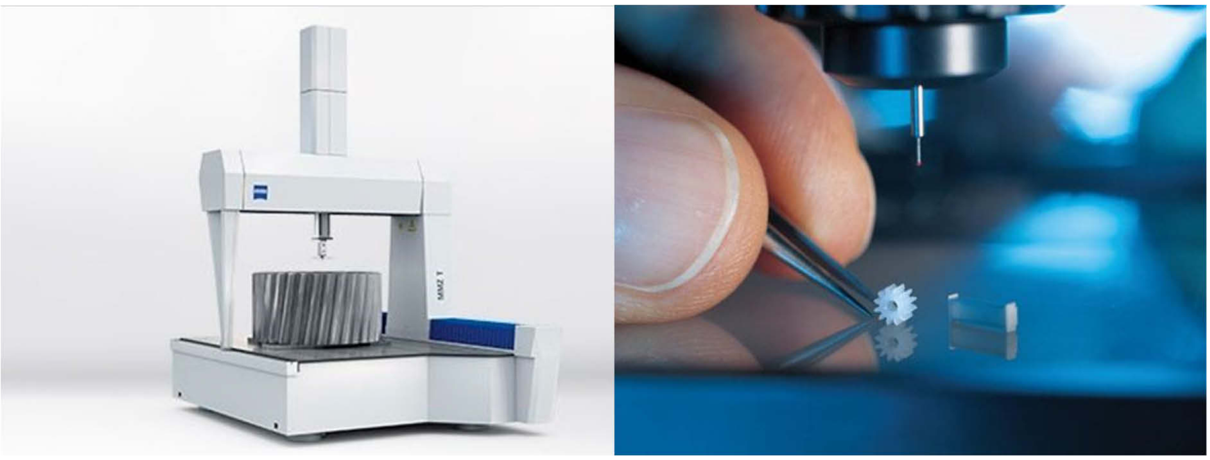

Figure 5: Range of gear metrology with coordinate measuring machines from macro-scale gears for wind energy systems [14] to micro-scale gears for watches [15].

As tolerances become tighter in macrometrology, e.g. for drives in wind power systems [14], greater accuracy of measuring instruments is required. In this context it is worth noting that, in response to the requirements of industrial quality inspection techniques from geodesy are being used more frequently in manufacturing metrology. Furthermore, progress in optical technology and fast low-cost computation leads to wide-spread application of laser trackers and digital photogrammetry for coordinate metrology [16].

In micrometrology higher levels of accuracy are also required as a result of increasing miniaturization [13].

Figure 6 shows the order of magnitude of these trends from an industrial perspective. There is a correlation between uncertainty and dimension very obvious. Additionally the need to check tighter tolerance for large dimensions is visible.

Demands for greater accuracy are also associated with the measurement of material properties [17] and electrical characteristics [18]. In this context it is not only important to optimize existing procedures but to monitor and correct environmental influences is equally if not more important.

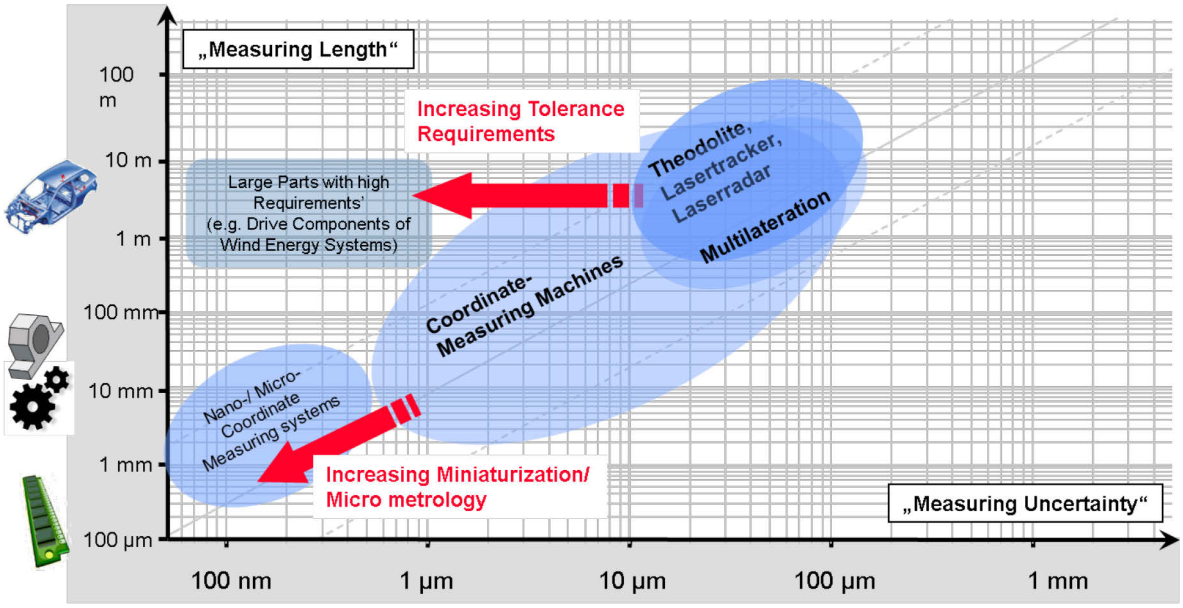

Figure 6: Trends of accuracy / measuring uncertainty in case of instruments used for length measurement.

4. RELIABLE

It has become increasingly important to consider measurement uncertainty when performing the conformity assessment of industrial products.

Standardized procedures for determining measurement uncertainty are becoming more established but they are also readily modified and customized based on the task at hand. A calibration of standards requires an even greater emphasis on determining measurement uncertainty than an inspection of product characteristics. As far as production is concerned, simplified procedures will become the industry standard. Documentation on measurement uncertainty will likely be required for product impacting the overall safety of manufactured goods in industries such as the medical devices and aviation and this practice will drive improvements in safety [19]. In addition, the computer-aided simulation of measurement processes based on the Monte-Carlo method [20] for determining measurement uncertainty will become more important. In the meantime, however, implementations have become available for different measurement methods, in most cases in the form of prototypes. In the field of coordinate metrology, systems already on the market (Figure 7) [22] are used specifically in the calibration of individual standards and normative publications are now available [23].

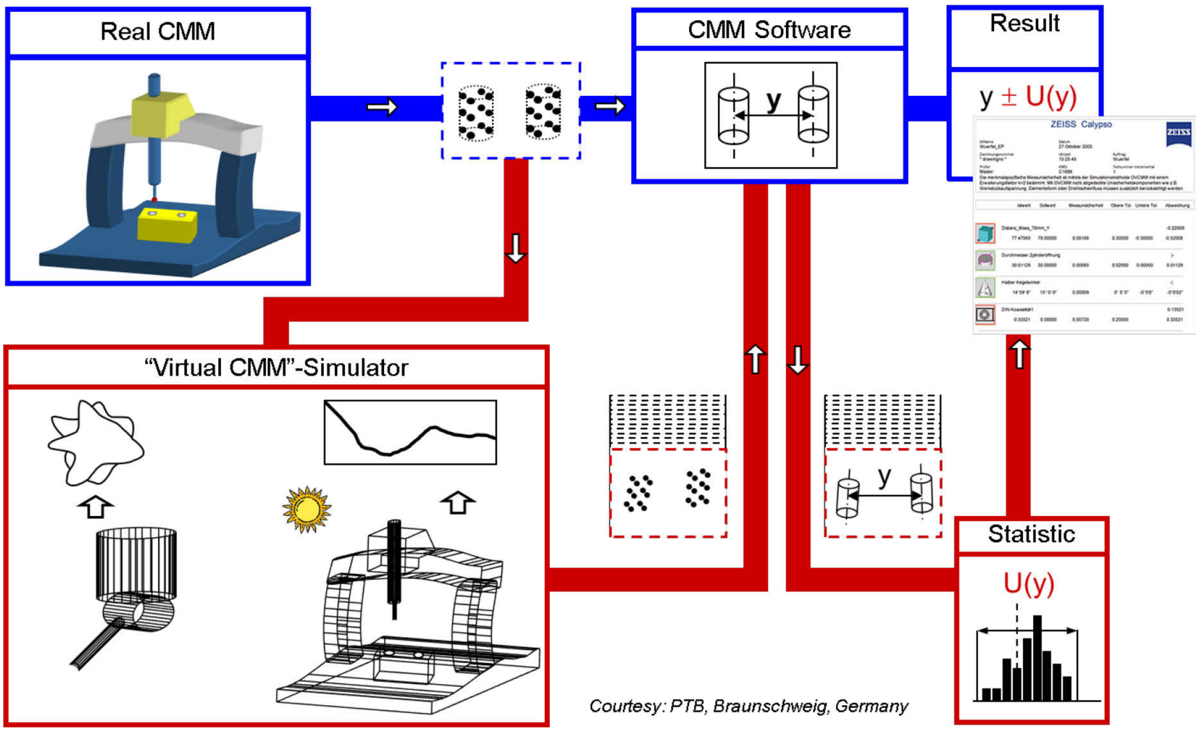

Figure 7: Determination of the measurement uncertainty of measurements in coordinate measuring machines by means of Monte-Carlo simulation: 'Virtual CMM' and its connection to the instrument software.

5. FLEXIBLE

The wide variety of measurement methods used in production is increasing and with it metrology is becoming more flexible and adaptable.

Different methods are often combined into measuring systems that are called "multisensor measuring machines" [24], Figure 8. The combination of results from several sensors is called sensor or data fusion [8, 24]. This boosts the flexibility of the systems. It does, however, also increase the complexity of measuring systems and therefore the demands imposed on the user with respect to training and the effort required to prepare for measurements.

6. HOLISITIC

Techniques are in use more and more which holistically register the shape of a product. These include fringe projection and photogrammetry [25]. With the help of computer tomography it is even possible to register structures not accessible from the outside [26]. Today computer tomography is used to locate defects in castings or for running dimensional plausibility checks, to name only a few applications. Computer tomography systems already attain measurement times which allow for their integration into the clock-pulse controlled production process - in other words, in-line utilization [27].

All these techniques require computer based control of the system and a computer based evaluation. The amount of the recorded data creates new challenges for the performance of the computer based processing. These needs go along with the computerization of manufacturing and manufacturing metrology according to "Industry 4.0".

The holistic techniques lead also to new presentation of the measured data. The color coded visualization of the deviations between actual data and nominal model (Figure 9) delivers easy to use information about product quality. But the representation requires a visual interpretation and it is often not usable for automatic evaluation. For a function oriented evaluation the tolerance characteristics defined according to ISO are not replaceable.

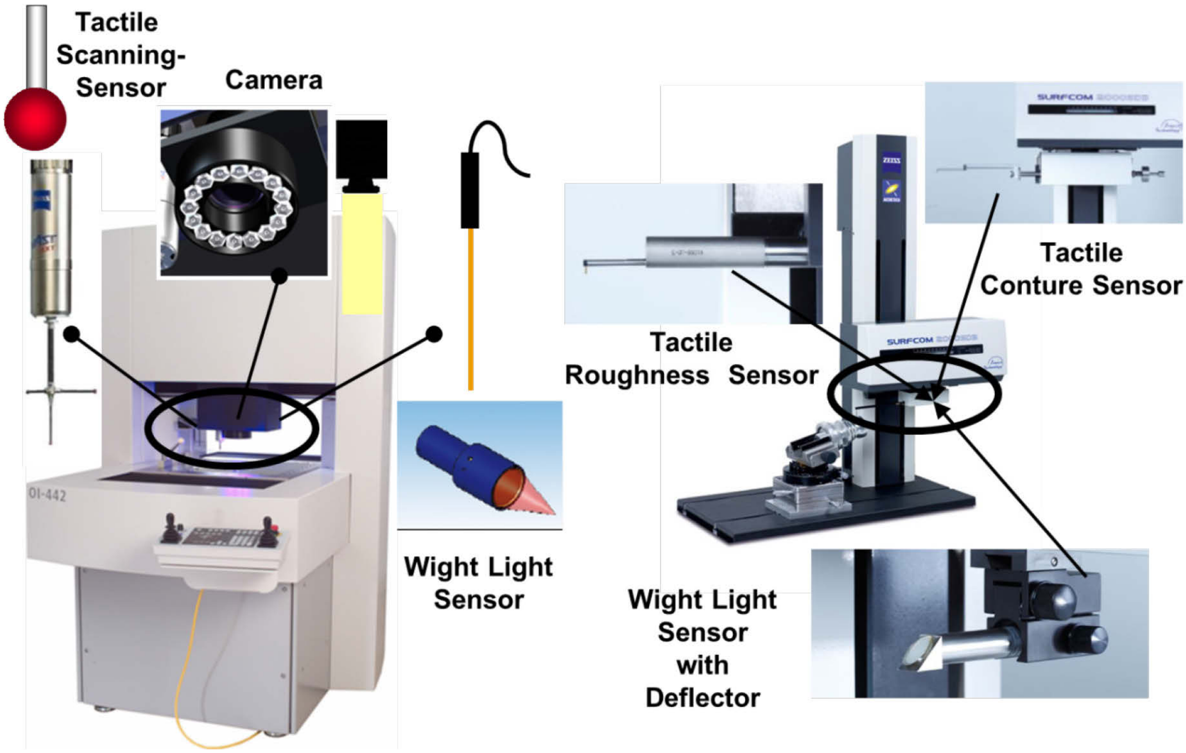

Figure 8: Types of Multisensor implementation: Parallel sensor implementation on a coordinate measuring machine (left), changeable sensor implementation on surface texture measuring device

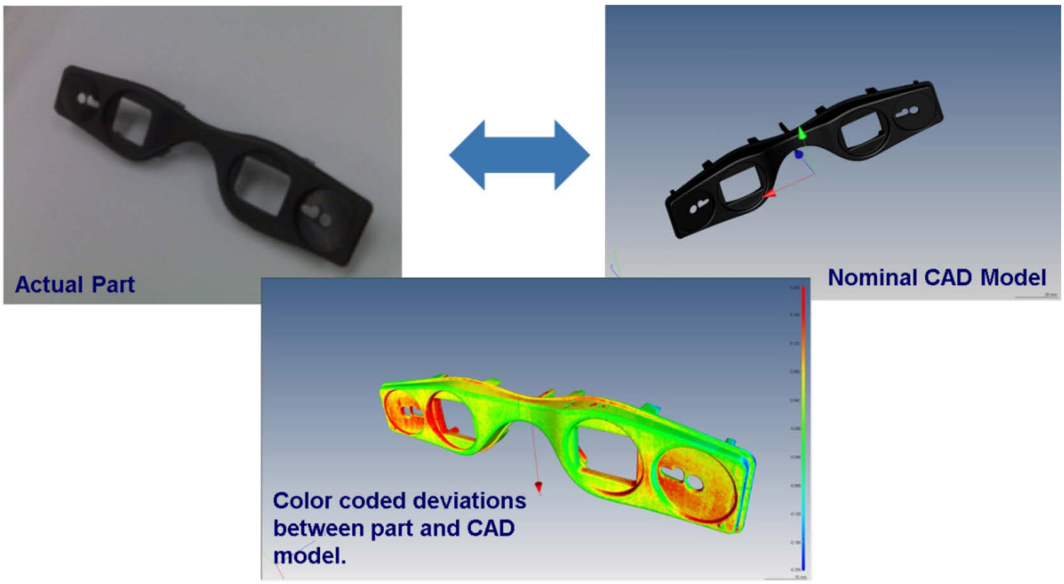

Figure 9: Color coded presentation of measuring results from a “holistic measuring system”

7. SUMMARY

Metrology will continue to grow in importance to industrial manufacturing and production. The increasing performance of metrology is reflected in its speed and levels of accuracy. At the same time it is becoming more flexible and can thus deliver more comprehensive information about production. Mastering the uncertainty of metrology in production will contribute to making production more efficient and products safer.

REMARK

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