Chapter 1

Introductory Chapter: Metrology

Anil Akdogan

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75541

1. Introduction

Metrology, the science of measurement, is crucial for manufacturing technologies. Since manufacturing has made huge leaps depending on the improvements in metrology, the book reflects recent developments in metrology in detail. This book focuses on dimensional and geometric measurements as well as technical testing and quality control applications in industry. It also intends the fundamentals of metrology concerning the related standards and systems of units. In addition, the book considers the calibration of measurement instruments and measurement uncertainties as the basic requirements of the related quality standards. Furthermore, it mentions the trends in micro and nanometrology and microscopic examinations. Topics covered in this book are of course not limited to them. The readers can find chapters about Metrology in a wide frame.

Physical properties such as length, weight, and temperature are determined by comparison with known quantities. In addition, measurement techniques are available in all engineering disciplines and allow for the creation and operation of all other scientific branches. In particular, measurement techniques are required at all levels of laboratory works. In fact, we practically measure many things: the weight of our body, the volume of our fuel oil, the temperature of the house, the noise at the factory, the distance between two points, etc. In addition to having an important place in our daily life, the measurement technique is the basis of almost all science branches such as Physics, Chemistry, and Biology. Measurement techniques are used to solve technical problems at all science branches. Theoretical hypotheses are supported by proving correctness by means of measurement technique by making necessary experiments and observations.

Metrology is the science of measurement. It covers all the practical and theoretical topics based on measurement, regardless of accuracy level and application area [1]. Measurement processes, measurement methods and procedures, instrumentation, calibration, determination of

measurement systems, verification, measurement accuracy, measurement precision, measurement error, data acquisition, evaluation of measurement results, the formation of statistical evaluations, and quality determinations are the main subjects of metrology.

The recognition that a measurement made by an industrial device is recognized worldwide and is the same as any other measurement made possible by achieving the highest precision basic measurement standard with a measurement reference chain. By fulfilling this, it is ensured that all the measurements carried out are accepted nationally and/or internationally. As a result, the calibration and verification processes have gained a great deal of importance. Calibration is a process of establishing a link between the values indicated by a measuring instrument or measuring system under certain conditions and the values obtained by a measuring instrument and corresponding values of corresponding measured values. With calibration, the measurement of a less precise measuring instrument or standard is carried out using an accepted standard of accuracy [2]. National metrology institutes are operating at the highest level, linked to the system by reference chain. These institutions are also linked to the Bureau International des Poids et Measure (BIPM) in central Paris in order to ensure that the measurements are internationally recognizable in a hierarchical structure. In the process of industrialization which started with serial production, it has become very important to establish a whole by combining the parts produced in different places, initiate specialization forms in the subsidiary industry and production, and make the measurements internationally recognizable.

The reliability of measuring instruments has increased at the same rate as the widespread use of microelectronics. Nowadays, measurement techniques are required to meet demands for faster, more accurate, and more flexible measurements. The documentation of measurement results is equally important. The development of precise manufacturing technology brings the need for more precise measuring technology. The developments in technology, especially in the field of measuring technology, have been the main reason for the increasing demands on the accuracy of the measurement. As micro and nanotechnologies have been used, it has become inevitable to develop devices and instruments that enable the measurement operations to be carried out at these accuracies.

New dimensions and research opportunities have been born in many scientific fields such as being in the electronics or molecular biology with nanotechnology. All of these disciplines are doing nanoscience studies on their own terms, and the opportunity to share all these different windows and share tools and techniques that develop independently is attractive to all sciences today. The placement of the atoms in the prescribed positions with the aid of nanotechnology is realized in this technology. Today the word “Nano” indicates a technique related to length measurements of very small objects in metrology, microtechnology, semiconductors, and nanotechnology fields. In nanometrology, the measurement size is typically specified as a nanometer. All applied methods are based on microscope technique with nano-position systems and position measurements at high accuracy. For instance, in mechanical engineering, nanotechnology and nanometrology are the necessary technologies to make a crystal perfect. The ability to precisely control the alignment of imprints and errors with respect to each other and the ability to integrate perfectly inorganic and organic nanostructures will lead to the emergence of a whole new generation of advanced composites. The improvements in technology intended to use the term *picotechnology* is a combination of picometer

and technology, parallel the term nanotechnology. Basic speckle metrology and autonomic computing resources are of course the most realistic uses of picotechnology. The ability to examine and manipulate resources at this level is quite useful. Of course, it is not difficult to imagine the tangible advantages of this type of technology.

2. Standardization in metrology

Standards are considered as measurement references. The basic standards about metrology are the basis of the traceability which is defined as a measurement whereby the result can be related to a reference through an unbroken chain of calibrations. Using internationally standardized systems of units, Vocabulary of Metrology (VIM), Guide to the International Uncertainty Measurements (GUM), or Internationally Standardized Measurement Management Systems [3] helps to improve the reliability of the results.

2.1. Unit of measurement

The most important condition of each measuring process and the manufacturing technique is the presence of units which are exactly defined according to the required quantities, and these units must be determined in accordance with internationally established rules. M*easurement* is a process that uses numbers to describe a physical quantity done to be able to compare them to each other. The results can be explained by a "*unit* of *measurement*," which is a definite magnitude of a quantity. The *SI,* The International System of *Units,* is the modern form of the metric system, and the most widely used system of measurement is made up of 7 base *units* that define the 22 derived *units* with special names and symbols. Base units provide the reference used to define all the measurement units of the system, while the derived units are products of base units and are used as measures of derived quantities. Derived units are the units obtained by algebraic operations from basic and auxiliary units. Certain derived units have special names and symbols like acceleration, meter per second squared, m s^{-2}.

2.2. Uncertainty of measurement

The uncertainty of a measurement is a predicament that characterizes the range of values, including the true value of the measure. *Measurement uncertainty* is an important topic for all measurement fields. All measurements have error. The error of a measurement is unknowable because one cannot know the error without knowing the true value of the quantity being measured. The *Evaluation of Measurement Data: Guide to the Expression of Uncertainty in Measurement* (GUM) provides general rules for evaluating and expressing uncertainty in measurement. The uncertainty of measurement generally includes many components. Some of these components can be estimated on the basis of the statistical distribution of series measurement results and can be characterized by empirical standard deviations. The estimates of the other components are based solely on the main information or experiences. The uncertainty of measurements should be evaluated and reported according to the related international standards.

2.3. Calibration

The purpose of calibration is to determine and document how much of the equipment is in error with the actual value. The correct value is obtained by considering the amount of error in the result. Calibration is the process of determining the relationship between the value read in a gauge and the gauge size. Calibration and control of measuring, inspection, and control equipments ensure the appropriateness of measurements made during manufacturing. The continuity of this safety is ensured by the regular and identifiable calibration of the equipment in question. Calibration is performed by comparison with a measurement of normality known to the measurement magnitude. To sum up, calibration is explained in the related standard: under specified conditions, the series of operations in which the relationship between the values indicated by a measuring instrument or device and the values indicated by a material measurement or reference material is established [3]. In order to supply traceability in measurements, calibration hierarchy in **Figure 1** should be followed up carefully.

3. Data evaluation

Metrology and inspection together serve as the control function of the quality of conformance. Inspection helps to evaluate the degree of conformance or nonconformance to specifications, provides for reporting of deficiencies early in the production process, and helps to assure that desired quality requirements have been met. The field of knowledge concerned with measurement. Metrology includes all aspects of both theoretical and practical with reference to measurements, whatever their level of accuracy, and in whatever fields of science or technology they occur. Since quality performance decisions are based on inspection and measurement, undesirable consequences may result if these tasks are not performed properly. Not only incorrect measurements lead to wrong decisions, which can have serious consequences, but also improper data evaluations can cause undesirable consequences. Since Statistical Process Control is the utilization of statisti-

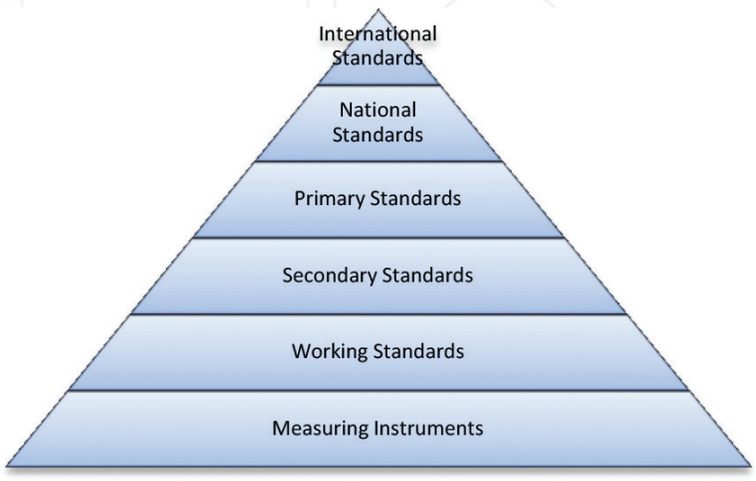

Figure 1. Hierarchy of calibration/traceability pyramid.

cal tools and methods to acquisite and to analyze data in order to monitor process capabilities, it is widely used in data evaluation. Quality control charts and the other statistical tools are used to analyze processes enabling appropriate actions to achieve improved or stabilized processes. They help to ensure that the process operates efficiently and allow organizations to understand variation in their processes, differentiating common causes from special or assignable causes of variation.

4. Conclusions

Metrology is a crucial science including its standards, systems of units, instruments, calibration procedures, uncertainties, inspection, and quality control topics in many industries such as automotive, aerospace, mechanical engineering, surface engineering, etc. and in many sciences like natural and applied sciences in different sizes like micro and nanometrology serving for sustainable improvements. Like being in today, there will always be valuable researches in the field of metrology, with the help of technological developments to support the scientific researches in the future. Care taken in the reliability of measurements and their traceability will always be crucial. Metrology is such useful for humanity if it is conducted according to its rules and international standards.

Acknowledgements

I would like to thank the authors for their contributions and the publisher that provided this opportunity.

Author details

Anil Akdogan

Address all correspondence to: nomak@yildiz.edu.tr

Mechanical Engineering Department, Yildiz Technical University, İstanbul, Turkey

References

[1] International Vocabulary of Metrology: Basic and General Concepts and Associated Terms. 3rd ed. VIM; 2012. JCGM 200:2012

[2] Uncertainty of measurement: Part 3: Guide to the expression of uncertainty in measurement. GUM; 1995. ISO/IEC Guide 98-3:2008

[3] Measurement management systems: Requirements for measurement processes and measuring equipment. 2003. ISO 10012:2003

IntechOpen