Dimensional Metrology Coordinate Measurements

This work presents the systematics of production metrology starting from the inspection planning, across the recording of the inspected data up to the evaluation of this data. On the one hand, the reader will be supplied with basic knowledge for the understanding of the presented procedures and their practical use. On the other hand, he will also learn about the importance of production metrology for quality control in production processes. It is not only an indispensable reference book for the daily work of the engineer, but also a invaluable and easy to read text book for students. As a supplement for the studies, the book gives a fast overlook to the basics of production metrology and, at the same time, shows how this knowledge is put into practice.

There is an increasing trend towards miniaturization of micro features as well as micro parts. In order to accurately produce these components and the miniaturized features on them, accurate measurement of the component dimensions is required. However, there are limitations in the dimensional measurement of miniature components: micro-probes and Micro coordinate machines (micro-CMMs) suitable for micro-feature measurement are expensive and fragile so it can be difficult to justify the cost for dimensional verification of batch-produced parts (in many cases miniature components are batch-produced). Therefore, a new cost-effective way for dimensional measurement of miniature components is needed. With this in mind, this thesis describes the development of a novel, three-dimensional measurement system using a rotating wire as a probe and acoustic emissions for contact sensing.This study presents a novel concept of three-dimensional measurements using a rotating wire as a probe and acoustic emission for contact sensing. Experimental results show that the probing system can measure a part with high repeatability. A controller algorithm has been developed for automated scanning within a machine tool. The performance is verified against calibration artifacts. The main contributions of this thesis are as follows: firstly, the traditional contact and non-contact micro coordinate measuring machines including sensing techniques and acoustic emission sensing are reviewed, and a clear set of knowledge gaps are identified in these fields. Secondly, a novel concept of three-dimensional measurements using a rotating wire as a probe tip and acoustic emission for contact sensing is introduced. The operation and measurements of the rotating micro probing based on acoustic emission (AE) sensing are validated experimentally. Initially, the ability of the rotating microprobe tip based on AE sensing to counteract the measured surfaces interaction rubbing is investigated. Other areas of validation are in the determination of the probing point repeatability, the straightness, and probe tip calibration. Thirdly, the acoustic emission signal and its characterizations of the probe tip touches are studied. The behavior of the rotating probe tip focusses on the threshold, touching time and as well as measured materials type that has an effect on probing accuracy. Finally, the estimated effective diameter and approximation threshold are modeled. This work is directly aimed at ensuring that the developed rotating probe tip based on AE sensing is capable of operating in an industrial metrology environment. It is concluded that the developed rotating probe tip based on AE sensing will be able to address the current needs of the micro-CMM community. On the other hand, it is possible that the rotating wire probe tip based on AE sensing can measure micro holes less than the achieved in this work, further

increasing its usefulness.

This collection represents successful invited submissions from the papers presented at the 8th Annual Conference of Energy Economics and Management held in Beijing, China, 22–24 September 2017. With over 500 participants, the conference was co-hosted by the Management Science Department of National Natural Science Foundation of China, the Chinese Society of Energy Economics and Management, and Renmin University of China on the subject area of “Energy Transition of China: Opportunities and Challenges”. The major strategies to transform the energy system of China to a sustainable model include energy/economic structure adjustment, resource conservation, and technology innovation. Accordingly, the conference and its associated publications encourage research to address the major issues faced in supporting the energy transition of China. Papers published in this collection cover the broad spectrum of energy economics issues, including building energy efficiency, industrial energy demand, public policies to promote new energy technologies, power system control technology, emission reduction policies in energy-intensive industries, emission measurements of cities, energy price movement, and the impact of new energy vehicle.

Reflecting the latest changes in standards and technology, market-leading FUNDAMENTALS OF DIMENSIONAL METROLOGY, 6e combines hands-on applications with authoritative, comprehensive coverage of the principles, techniques, and devices used within today's dimensional metrology field. The Sixth Edition has been thoroughly revised and updated in direct response to reviewer feedback. The new edition features an easier to understand presentation, a new lab manual/workbook, updated photos and illustrations and updated references to measurement standards.. The text continues to use both metric and imperial systems but emphasizes metric measurement devices and concepts in all examples for greater consistency with the latest industry trends. Important Notice: Media content referenced within the product description or the product text may not be available in the ebook version.

The field of large-scale dimensional metrology (LSM) deals with objects that have linear dimensions ranging from tens to hundreds of meters. It has recently attracted a great deal of interest in many areas of production, including the automotive, railway, and shipbuilding sectors. Distributed Large-Scale Dimensional Metrology introduces a new paradigm in this field that reverses the classical metrological approach: measuring systems that are portable and can be easily moved around the location of the measured object, which is preferable to moving the object itself. Distributed Large-Scale Dimensional Metrology combines the concepts of distributed systems and large scale metrology at the application level. It focuses on the latest insights and challenges of this new generation of systems from the perspective of the designers and developers. The main topics are: coverage of measuring area, sensors calibration, on-line diagnostics, probe management, and analysis of metrological performance. The general descriptions of each topic are further enriched by specific examples concerning the use of commercially available systems or the development of new prototypes. This will be particularly useful for professional practitioners such as quality engineers, manufacturing and development engineers, and procurement specialists, but Distributed Large-Scale Dimensional Metrology also has a wealth of information for interested academics.

Due to their speed, data density, and versatility, optical metrology tools play important roles in today's high-speed industrial manufacturing applications. Handbook of Optical Dimensional Metrology provides useful background information and practical examples to help readers understand and effectively use state-of-the-art optical metrology methods. The book first builds a foundation for evaluating optical measurement methods. It explores the many terms of optical metrology and compares it to other forms of metrology, such as mechanical gaging, highlighting the limitations and errors associated with each mode of measurement at a general level. This comparison is particularly helpful to current industry users who operate the most widely applied mechanical tools. The book then focuses on each application area of measurement, working down from large area to medium-sized to submicron measurements. It describes the measurement of large objects on the scale of buildings, the measurement of durable manufactured goods such as aircraft engines and appliances, and the measurement of fine features on the micron and nanometer scales. In each area, the book covers fast, coarse measures as well as the finest measurements possible. Best practices and practical examples for each technology aid readers in effectively using the methods. Requiring no prior expertise in optical dimensional metrology, this handbook helps engineers and quality specialists understand the capabilities and limitations of optical metrology methods. It also shows them how to successfully apply optical metrology to a vast array of current engineering and scientific problems.

This book examines an intelligent system for the inspection planning of prismatic parts on coordinate measuring machines (CMMs). The content focuses on four main elements: the engineering ontology, the model of inspection planning for prismatic parts on CMMs, the optimisation model of the measuring path based on an ant-colony approach, and the model of probe configuration and setup planning based on a genetic algorithm. The model of inspection planning for CMMs developed here addresses inspection feature construction, the sampling strategy, probe accessibility analysis, automated collision-free operation, and probe path planning. The proposed model offers a novel approach to intelligent inspection, while also minimizing human involvement (and thus the risk of human error) through intelligent planning of the probe configuration and part setup. The advantages of this approach include: reduced preparation times due to the automatic generation of a measuring protocol; potential optimisation of the measuring probe path, i.e., less time needed for the actual measurement; and increased planning process autonomy through minimal human involvement in the setup analysis and probe configuration.

Dimensional measurement plays a critical role in product development and quality control. With the continuously increasing demand for tighter tolerances and more complex workpiece shapes in the industry, dimensional metrology often becomes the bottleneck of taking the quality and performance of manufacturing to the next level. As one kind of the most useful and powerful measuring instruments, coordinate measuring machines (CMMs) are widely employed in manufacturing industries. Since the accuracy and efficiency of a CMM have a vital impact on the product quality, productivity and manufacturing cost, the evaluation and improvement of CMM performance have always been important research topics since the invention of CMM. A novel Advanced Virtual Coordinate Measuring Machine (AVCMM) is proposed against such a background. The proposed AVCMM is a software package that provides an integrated virtual environment, in which user can plan inspection strategy for a given task, carry out virtual measurement, and evaluate the uncertainty associated with the measurement result, all without the need of using a physical machine. The obtained estimate of uncertainty can serve as a rapid feedback for user to

optimize the inspection plan in the AVCMM before actual measurement, or as an evaluation of the result of a performed measurement. Without involving a physical CMM in the inspection planning or evaluation of uncertainty, the AVCMM can greatly reduce the time and cost needed for such processes. Furthermore, as the package offers vivid 3D visual representation of the virtual environment and supports operations similar to a physical CMM, it does not only allow the user to easily plan and optimise the inspection strategy, but also provide a cost-effective, risk-free solution for training CMM operators. A modular, multitier architecture has been adopted to develop the AVCMM system, which incorporates a number of functional components covering CMM and workpiece modelling, error simulation, inspection simulation, feature calculation, uncertainty evaluation and 3D representation. A new engine for detecting collision/contact has been developed and utilized, which is suitable for the virtual environment of simulated CMM inspections. A novel approach has been established to calculate errors required for the error simulation, where the data are obtained from FEA simulations in addition to conventional experimental method. Monte Carlo method has been adopted for uncertainty evaluation and has been implemented with multiple options available to meet different requirements. A prototype of the proposed AVCMM system has been developed in this research. Its validity, usability and performance have been verified and evaluated through a set of experiments. The principles for utilising the AVCMM in practical use have also been established and demonstrated. The results have indicated that the proposed AVCMM system has great potentials to improve the functionalities and overall performance of CMMs.

Metrology and Instrumentation: Practical Applications for Engineering and Manufacturing provides students and professionals with an accessible foundation in the metrology techniques, instruments, and governing standards used in mechanical engineering and manufacturing. The book opens with an overview of metrology units and scale, then moves on to explain topics such as sources of error, calibration systems, uncertainty, and dimensional, mechanical, and thermodynamic measurement systems. A chapter on tolerance stack-ups covers GD&T, ASME Y14.5-2018, and the ISO standard for general tolerances, while a chapter on digital measurements connects metrology to newer, Industry 4.0 applications.

Over the last decade of the 20th century, many improvements took place in the field of metrology and fundamental constants. These developments and improvements are discussed in this book. The old caesium SI second definition has found a new realization with the fountain approach, replacing the classical thermal atomic beam. The use of cold atom techniques, slowed down and cooled, has opened a number of unexpected avenues for metrology and fundamental constants, one of these possibilities being the atom interferometry. Another development was the demonstration of the possiblility of performing a direct frequency division in the visible, using short femtosecond pulses. Many other developments are also discussed.

This Springer Handbook of Metrology and Testing presents the principles of Metrology – the science of measurement – and the methods and techniques of Testing – determining the characteristics of a given product – as they apply to chemical and microstructural analysis, and to the measurement and testing of materials properties and performance, including modelling and simulation. The principal motivation for this Handbook stems from the increasing demands of technology for measurement results that can be used globally. Measurements within a local laboratory or manufacturing facility must be able to be reproduced accurately anywhere in the world. The book integrates knowledge from basic sciences and engineering disciplines, compiled by experts from internationally known metrology and testing institutions, and academe, as well as from industry, and conformity-assessment and accreditation bodies. The Commission of the European Union has expressed this as there is no science without measurements, no quality without testing, and no global markets without standards.

Traceable calibration of test and measurement equipment is a requirement of the ISO 9000 series of standards. Basic Metrology for ISO 9000 Certification provides essential information for the growing number of firms registered for ISO 9000. Dr. G.M.S. de Silva who has a lifetime of experience in metrology and quality management fields condenses that knowledge in this valuable and practical workbook. The book provides a basic understanding of the principles of measurement and calibration of measuring instruments falling into the following fields; Length,Angle, Mass, Pressure, Force, Temperature and AC/DC Electrical quantities. Basic concepts and definitions, ISO 9001 requirements and uncertainty determinations are also included.

Nineteen Fact-Filled Charters that contain authoritative treatment of all aspects of dimensional measurement technology make Handbook of Dimensional Measurement the most readable and comprehensive guide available for engineers and technicians engages in the various stages of industrial production. Design engineers, manufacturing engineers, tool and gage makers, quality control specialists, and reliability experts will find a wealth of practical data as well as complete coverage - both basic and advanced - of dimensional measurement techniques and equipment. The Third Edition of this classic book has been completely revised to include the computer and electronics revolution in metrology. Virtually every type of measurement instrument and machine, even the newest devices, can be found in these pages. Hundreds of changes, and additions and scores of new illustrations have been incorporated to assure that Handbook of Dimensional Measurement retains its status as the standard reference for the practitioner of dimensional measurement.

X-ray computed tomography has been used for several decades as a tool for measuring the three-dimensional geometry of the internal organs in medicine. However, in recent years, we have seen a move in manufacturing industries for the use of X-ray computed tomography; first to give qualitative information about the internal geometry and defects in a component, and more recently, as a fully-quantitative technique for dimensional and materials analysis. This trend is primarily due to the ability of X-ray computed tomography to give a high-density and multi-scale representation of both the external and internal geometry of a component, in a non-destructive, non-contact and relatively fast way. But, due to the complexity of X-ray computed tomography, there are remaining metrological issues to solve and the specification standards are still under development. This book will act as a one-stop-shop resource for students and users of X-ray computed tomography in both academia and industry. It presents the fundamental principles of the technique, detailed descriptions of the various components (hardware and software), current developments in calibration and performance verification and a wealth of example applications. The book will also highlight where there is still work to do, in the perspective that X-ray computed tomography will be an essential part of Industry 4.0.

In the latter half of the 20th century, forces have conspired to make the human community, at last, global. The easing of tensions between major nations, the expansion of trade to worldwide markets, widespread travel and cultural exchange, pervasive high-speed communications and automation, the explosion of knowledge, the streamlining of business, and the adoption of flexible methods have changed the face of manufacturing itself, and of research and education in manufacturing. The acceptance of the continuous improvement process as a means for organizations to respond quickly and effectively to swings in the global market has led to the demand for individuals educated in a broad range of cultural, organizational, and technical fields and capable of absorbing and adapting required knowledge and training throughout their careers. No longer will manufacturing research and education focus on an industrial sector or follow a national trend, but rather will aim at enabling international teams of companies to cooperate in rapidly designing, prototyping, and manufacturing products. The successful enterprise of the 21st century will be characterized by an organizational structure that efficiently responds to customer demands and

changing global circumstances, a corporate culture that empowers employees at all levels and encourages constant communication among related groups, and a technological infrastructure that fully supports process improvement and integration. In changing itself to keep abreast of the broader transformation in manufacturing, the enterprise must look first at its organization and culture, and thereafter at supporting technologies.

Since John Bosch edited and published the first version of this book in 1995, the world of manufacturing and coordinate measuring machines (CMMs) and coordinate measuring systems (CMSs) has changed considerably. However, the basic physics of the machines has not changed in essence but have become more deeply understood. Completely revised and updat

Dimensional metrology is an essential part of modern manufacturing technologies, but the basic theories and measurement methods are no longer sufficient for today's digitized systems. The information exchange between the software components of a dimensional metrology system not only costs a great deal of money, but also causes the entire system to lose data integrity. Information Modeling for Interoperable Dimensional Metrology analyzes interoperability issues in dimensional metrology systems and describes information modeling techniques. It discusses new approaches and data models for solving interoperability problems, as well as introducing process activities, existing and emerging data models, and the key technologies of dimensional metrology systems. Written for researchers in industry and academia, as well as advanced undergraduate and postgraduate students, this book gives both an overview and an in-depth understanding of complete dimensional metrology systems. By covering in detail the theory and main content, techniques, and methods used in dimensional metrology systems, Information Modeling for Interoperable Dimensional Metrology enables readers to solve real-world dimensional measurement problems in modern dimensional metrology practices.

Public Accountability: Evaluating Technology-Based Institutions presents guidelines for evaluating the research performance of technology-based public institutions, and illustrates these guidelines through case studies conducted at one technology-based public institution, the National Institute of Standards and Technology (NIST). The aim of this book is to demonstrate that a clear, more precise response to the question of performance accountability is possible through the systematic application of evaluation methods to document value. The authors begin with a review of the legislative history of fiscal accountability beginning with the Budget and Accounting Act of 1921, and ending with the Government Performance and Results Act of 1993. A discussion of existing applicable economic models, methods, and associated metrics follows. The book concludes with evaluation case studies.

Three-dimensional Metrology of Video Coordinate Measuring Machines

ABSTRACT: The three-dimensional metrological nature of video coordinate measuring machines is explored. The video coordinate measuring machine, or video CMM, is a variant of the widely used CMM in dimensional metrology. The video CMM utilizes a camera-based video probe sensor instead of the traditional contact probe sensor. Video probes, in general, do not have true three-dimensional measurement capability, and therefore many of the metrology techniques and performance tests that are commonly used with contact probe CMMs are not applicable or are not possible using video CMMS. Based on underlying metrology principles and on typical implementations, a classification scheme is introduced for measurements made with video CMMS. The theory behind each class is discussed, performance tests are

proposed, and experimental data are presented. The acceptable use of various metrology artifacts is also tested, and two novel artifact designs are presented for metrology use on video CMMS. The uncertainty in calibrating the actual magnification of the video probe is also investigated. The results show a serious need for the development of standardized performance tests and for the better understanding of three-dimensional metrology issues by the video CMM community.

This book gathers the proceedings of the 12th International Conference on Measurement and Quality Control – Cyber Physical Issues (IMEKO TC 14 2019), held in Belgrade, Serbia, on 4–7 June 2019. The event marks the latest in a series of high-level conferences that bring together experts from academia and industry to exchange knowledge, ideas, experiences, research findings, and information in the field of measurement of geometrical quantities. The book addresses a wide range of topics, including: 3D measurement of GPS characteristics, measurement of gears and threads, measurement of roughness, micro- and nano-metrology, laser metrology for precision measurements, cyber physical metrology, optical measurement techniques, industrial computed tomography, multisensor techniques, intelligent measurement systems, evaluating measurement uncertainty, dimensional management in industry, product quality assurance methods, and big data analytics. By providing updates on key issues and highlighting recent advances in measurement and quality control, the book supports the transfer of vital knowledge to the next generation of academics and practitioners.

Dimensional Metrology is the branch of science that determines length, angular, and geometric relationships within manufactured parts and compares them with required tolerances. The measurements can be made using either manual methods or sampled coordinate metrology (Coordinate measuring machines). Manual measurement methods have been in practice for a long time and are well accepted in the industry, but are slow for the present day manufacturing. On the other hand CMMs are relatively fast, but these methods are not well established yet. The major problem that needs to be addressed is the type of feature fitting algorithm used for evaluating tolerances. In a CMM the use of different feature fitting algorithms on a feature gives different values, and there is no standard that describes the type of feature fitting algorithm to be used for a specific tolerance. Our research is focused on identifying the feature fitting algorithm that is best used for each type of tolerance. Each algorithm is identified as the one to best represent the interpretation of geometric control as defined by the ASME Y14.5 standard and on the manual methods used for the measurement of a specific tolerance type. Using these algorithms normative procedures for CMMs are proposed for verifying tolerances. The proposed normative procedures are implemented as software. Then the procedures are verified by comparing the results from software with that of manual measurements. To aid this research a library of feature fitting algorithms is

developed in parallel. The library consists of least squares, Chebyshev and one sided fits applied on the features of line, plane, circle and cylinder. The proposed normative procedures are useful for evaluating tolerances in CMMs. The results evaluated will be in accordance to the standard. The ambiguity in choosing the algorithms is prevented. The software developed can be used in quality control for inspection purposes.

This work reviews the basic concepts of co-ordinate metrology. It defines what co-ordinate measuring machines (CMMs) are and details how they can be applied to gain a competitive advantage in a variety of business settings, from small machine shops to global manufacturers. Areas that are critical for the successful application of CMMs - including environmental factors, the measuring of speed and accuracy, traceability, versatility and programming methodology - are considered.;The book is intended for manufacturing, mechanical, quality control, design, industrial, automation, automotive and aerospace engineers and managers, as wel as upper-level undergraduate and graduate students in these disciplines.;College or university bookstores may order five or more copies at a special student price, which is available from Marcel Dekker Inc upon request.

Methods presented involve the use of simulation and modeling tools and virtual workstations in conjunction with a design environment. This allows a diverse group of researchers, manufacturers, and suppliers to work within a comprehensive network of shared knowledge. The design environment consists of engineering workstations and servers and a suite of simulation, quantitative, computational, analytical, qualitative and experimental tools. Such a design environment will allow the effective and efficient integration of complete product design, manufacturing process design, and customer satisfaction predictions. This volume enables the reader to create an integrated concurrent engineering design and analysis infrastructure through the use of virtual workstations and servers; provide remote, instant sharing of engineering data and resources for the development of a product, system, mechanism, part, business and/or process, and develop applications fully compatible with international CAD/CAM/CAE standards for product representation and modeling.

Manufacturing and Automation Systems: Techniques and Technologies, Part 5 of 5

Advances in metrology depend on improvements in scientific and technical knowledge and in instrumentation quality, as well as better use of advanced mathematical tools and development of new ones. In this volume, scientists from both the mathematical and the metrological fields exchange their experiences. Industrial sectors, such as instrumentation and software, are likely to benefit from this exchange, since metrology has a high impact on the overall quality of industrial products, and applied mathematics is becoming more and more important in industrial processes.This book is of interest to people in universities, research centers and industries who are involved in measurements and need advanced mathematical tools to solve their problems, and to those developing such mathematical tools.

The importance of proper geometric dimensioning and tolerancing as a means of expressing the designer's functional intent and controlling the inevitable geometric and dimensional variations of mechanical parts and assemblies, is becoming well recognized. The research efforts

and innovations in the field of tolerancing design, the development of supporting tools, techniques and algorithms, and the significant advances in computing software and hardware all have contributed to its recognition as a viable area of serious scholarly contributions. The field of tolerancing design is successfully making the transition to maturity where deeper insights and sound theories are being developed to offer explanations, and reliable implementations are introduced to provide solutions. Machine designers realized very early that manufacturing processes do not produce the nominal dimensions of designed parts. The notion of associating a lower and an upper limit, referred to as tolerances, with each dimen sion was introduced. Tolerances were specified to ensure the proper function of mating features. Fits of mating features included clearances, location fits, and interference fits, with various sub-grades in each category assigned a tolerance value depending on the nominal size of the mating features. During the inspection process, a part is rejected if a dimension fell outside the specified range. As the accuracy requirements in assemblies became tighter, designers had to consider other critical dimensions and allocate tolerances to them in order to ensure the assembly's functionality.

The current way to choose X-ray computed tomography (XCT) scanning settings is usually manual and prone to operator errors. This paper presents an effective semiautomatic protocol that proves a high correlation between the local contrast-to-noise (CNR) of XCT two-dimensional (2D) projection image (prior to reconstruction) quality and the resulting XCT 3D volume scan quality. This high correlation allowed the comparison of four XCT settings to determine the one with the smallest error, solely by locally using the CNR equation on one 2D projection (prior to reconstruction) of an additive manufactured lattice structure. Verification of the protocol was done by using a workpiece and comparing the chosen XCT setting reconstructed workpiece dimensions to the ones measured using a coordinate-measuring machine (CMM). This new method can reduce the operator error and time needed to compare different XCT setting combinations. The proposed protocol is a step closer to an automated XCT parameter selection procedure, limiting user dependency and error while increasing accuracy and fidelity.

Geometric tolerances are changing the way we design and manufacture industrial products. Geometric Tolerances covers their impact on the world of design and production, highlighting new perspectives, possibilities, current issues and future challenges. The topics covered are designed to be relevant to readers from a variety of backgrounds, ranging from product designers and manufacturers to quality inspection engineers and quality engineers involved in statistical process monitoring. Areas included are: • selection of appropriate geometric tolerances and how they stack up in assembled products; • inspection of parts subjected to geometric tolerancing from the macro to the micro and sub-micro scales; and • enhancement of efficiency and efficacy of quality monitoring. Geometric Tolerances provides the reader with the most recent scientific research in the field, as well as with a significant amount of real-life industrial case studies, delivering a multidisciplinary, synoptic view of one of the hottest and most strategic topics in industrial production.

The quantitative determination of the properties of micro- and nanostructures is essential in research and development. It is also a prerequisite in process control and quality assurance in industry. The knowledge of the geometrical dimensions of structures in most cases is the base, to which other physical and chemical properties are linked. Quantitative measurements require reliable and stable instruments, suitable measurement procedures as well as appropriate calibration artefacts and methods. The seminar "NanoScale 2004" (6th Seminar on Quantitative Microscopy and 2nd Seminar on Nanoscale Calibration Standards and Methods) at the National Metrology Institute (Physikalisch-Technische Bundesanstalt PTB), Braunschweig, Germany, continues the series of seminars on Quantitative Microscopy. The series stimulates the exchange of information between manufacturers of relevant hard- and software and the users in science and industry. Topics

addressed in these proceedings are a) the application of quantitative measurements and measurement problems in: microelectronics, microsystems technology, nano/quantum/molecular electronics, chemistry, biology, medicine, environmental technology, materials science, surface processing b) calibration & correction methods: calibration methods, calibration standards, calibration procedures, traceable measurements, standardization, uncertainty of measurements c) instrumentation and methods: novel/improved instruments and methods, reproducible probe/sample positioning, position-measuring systems, novel/improved probe/detector systems, linearization methods, image processing