AUTOMATION AND CONTROL COLLECTION

MEASUREMENT AND MONITORING

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Abstract

This book presents the main methods and techniques for measuring and monitoring the accuracy of geometrical parameters of precision Computer Numerically Controlled (CNC) and automated machines, including modern coordinate measuring machines (CMMs). Standard methods and means of testing are discussed, together with methods newly developed and tested by the authors. Various parameters, such as straightness, perpendicularity, flatness, pitch, yaw, roll, and so on, are introduced and the principal processes for measurement of these parameters are explained. Lists and tables of geometrical accuracy parameters, together with diagrams of arrangements for their control and evaluation of measurement results, are added. Special methods and some original new devices for measurement and monitoring are also presented. Information measuring systems, consisting of laser interferometers, photoelectric raster encoders or scales, and so on, are discussed and methods for the measurement and testing of circular scales, length scales, and encoders are included. Particular attention is given to the analysis of ISO written standards of accuracy control, terms and definitions, and methods for evaluation of the measurement results during performance verification. Methods for measuring small lengths, gaps, and distances between two surfaces are also presented. The resolution of measurement remains very high, at least within the range 0.05 μm to 0.005 μm.

The problem of complex accuracy control of machines is discussed and different methods for accuracy control are described. The technical solution for complex measurement using the same kind of machine, as a master or reference machine, together with the laser interferometer and fiber optic links is presented.

Comparators for the accuracy measurement of linear and angular standards are described, and the accuracy characteristics of these standards are investigated. Accuracy improvement systems using machines are described and examples are given showing the suitability of mechatronic methods for high-accuracy correction and measurement arrangements.

The effectiveness of the application of piezoelectric actuators is demonstrated using the construction of a comparator for angular measurements as an example.

Some mechatronic methods for accuracy improvement of multi-coordinate machines are proposed. These methods control the accuracy of the displacement of parts of the machine, of the transducers or the final member of the kinematic chain of the machine, such as the touch-probe or the machine cutting tool. Some categories of errors may be improved by numerical control means, because they are determined in the form of a graph with some peaks along the measuring axis running off accuracy limits. These points, as numerical values, are provided as inputs to the control device or to the display unit of the transducer and can be corrected at appropriate points of displacement. The idea is introduced for accomplishing the correction by calculating the correctional coefficients in all coordinate directions and the correctional displacement to be performed using the last (conclusive) part of the machine. For example, the last mentioned part may be the grip of the arm of an industrial robot, the touch-trigger probe of a CMM (measuring robot), the cutting instrument or the holder of metal cutting tools, and so on. In this case piezoelectric plates, in the form of cylindrical or spherical bodies, may be incorporated into the last machine member for this purpose.

The experience gained by the authors working at industrial plants and universities, performing EU research projects and international RTD projects, is used throughout the book.

KEYWORDS

monitoring, measurement, machine monitoring, calibration, performance verification, coordinate measuring machines, linear scales and transducers, circular scales, nano-displacement

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About the Authors

Vytautas Giniotis

Vytautas Giniotis was employed as Chief Scientific Worker in the Institute of Geodesy, Vilnius Gediminas Technical University, Lithuania, from 2003 until his tragic sudden death in 2012. He had a most distinguished career lasting over 50 years in both industry and academia. His major scientific interests were measurements and instrumentation, 3D measurements, mechatronics in metrology, research into the accuracy of linear and angular transducers, GPS accuracy investigation, and instrument calibration.

He graduated as Dipl. Mechanical Engineer from Kaunas Polytechnic Institute in 1961 and obtained his PhD from the same institution in 1975. His industrial experience covered a period of over 30 years and included a five-year term as Chief Metrologist and Head of the Metrology and Quality Control Department at Vilnius State Grinding Machines Factory between 1989 and 1994. He joined Vilnius Gediminas Technical University in 1994, was awarded Doctor Habilitus in 1996 and appointed as a Professor in 1998.

He is the author of one monograph and the co-author of another one. He has published more than 220 scientific papers in peer-reviewed international journals and international conferences worldwide. He has also published three booklets in his field and has 55 patents and inventions. He was Lithuania's State Science Award winner in 2009 and was an expert member of the Lithuanian Science Council between 2003 and 2008. He was actively involved in collaborative research projects funded by the European Union and was also an Expert Evaluator of European research proposals submitted to the European Commission in Brussels.

Anthony Hope

Anthony Hope is currently Professor of Automation and Control at Southampton Solent University, United Kingdom. He has had a long career in both industry and academia and has worked at Southampton Solent

University since 1990. His major scientific interests include condition monitoring of machines, performance verification of machine tools and coordinate measuring machines, instrumentation and control, materials testing and evaluation.

He graduated from Leeds University in 1964 with a BSc (1st Honours) in Fuel Technology and then spent several years in industry working on the design and development of aircraft fuel systems. He joined Birmingham Polytechnic in 1970 as a Lecturer in Mechanical Engineering and was then awarded his PhD in Mechanical Engineering from Birmingham University in 1976. He has extensive consultancy and research experience in condition monitoring, engineering materials, machine tool calibration, nondestructive testing, and instrumentation and control. He is a Chartered Engineer, an Honorary Fellow of the British Institute of Non-Destructive Testing and a Foundation Fellow of the International Society of Engineering Asset Management.

He is the co-author of one textbook, *Engineering Measurements*, and has written chapter contributions in two further textbooks. He has also published well over 100 scientific papers in technical journals and refereed international conference proceedings. He has collaborated in a number of major European research projects and was awarded the condition monitoring and diagnostic technology (COMADIT) prize in 2008 by the British Institute of Non-Destructive Testing for his contribution to the benefit of industry and society through research and development in condition monitoring.

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CHAPTER 1

Monitoring of Processes, Systems, and Equipment

In this chapter, the methods and means for the monitoring of technical parameters of machines are presented. The mutual interaction between the measurement and monitoring procedures is discussed, and the different levels of monitoring the parameters of a machine are considered in terms of the global, local, and component levels. The importance of sampling procedures is introduced and various sampling strategies for the dimensional measurement of the geometric features of coordinate measuring machines (CMMs) and other machines are discussed.

The importance of determining the information quantity on an assessed object is illustrated; thus providing more complete measurement during the calibration process. Systematic errors and uncertainty in the calibration of linear and circular raster scales are included and probability theory provides a statistical means for evaluating the results of measurement by selecting the pitch of measurement, assessing the set of trials, calculating the mean value of estimates, and evaluating the dispersion at the probability level chosen. The general process presented here provides information on the conditions of measurement performed, as it includes sampling, together with systematic error and uncertainty evaluation.

1.1 INTRODUCTION

The *Concise Encyclopedia of Condition Monitoring* [1] gives an explanation for the main terms and expressions used for the monitoring process. On the basis of the Concise Encyclopedia, system monitoring could be expanded to include a wider scope of the monitoring process. It would include features covering both an upper and a lower level of monitoring.

It can be treated in terms of *global, local, and component* levels of monitoring. The global level includes space and world phenomena, including space satellites and probes, earth and planet investigations, atmosphere phenomena, and environmental processes. An industrial monitoring process can be designated to the global level, followed by the system level, plant level, and machine and equipment level as the components of analysis.

Some authors [2,3] present the analysis of configuring a measurement and monitoring system in the construction, machine engineering industry, and other branches of industry and social activities. The monitoring systems are analyzed to detect the failure of the machine, control the level of vibration, leakage in a water supply network, environment contamination level, and so on. A number of sensors are used within the system for monitoring.

The methodology for measurement system configuration is based on the choice of the system's parameters to be controlled, the limits of the parameters, sample selection, development of the measurement and/or control system, including selection of sensors, selection of information, processing of information, data transfer, and decision making. A general diagram showing the mutual interaction between the measurement and monitoring procedures is shown in Figure 1.1.

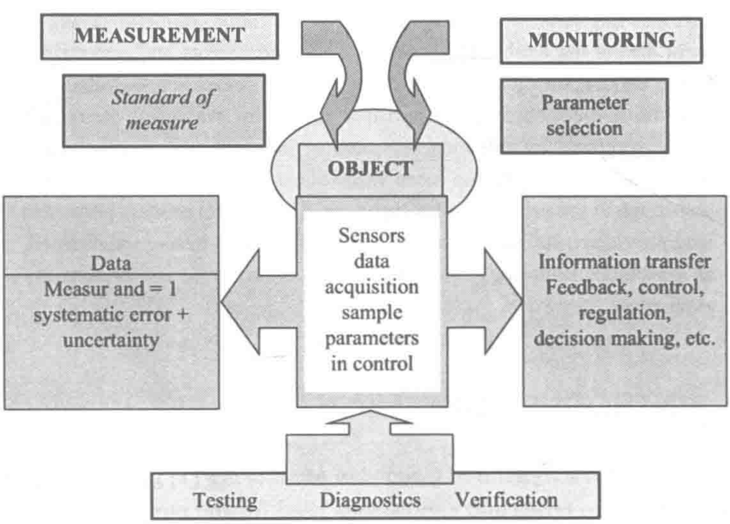

Figure 1.1. General diagram of mutual interaction of measurement and monitoring procedures.