

Design for Precision: Current Status and Trends

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Abstract

'Design for Precision' reviews the status quo in Precision Engineering and concludes that today's precision engineers put repeatability at the top of their list. The design rules, patterns or principles, quoted here from various authors, are all time-proven insights, to get reproducible results with ultra precision machines and instruments. Modelling and analysis of different concepts, systems, and components is required to adapt the progressing design or to confirm its adequacy. Expenditure on such analysis is worthwhile to avoid realisation of an inadequate design. However, creativity is more important in keeping the cost down by finding other than locally optimised solutions. World-wide, precision engineers agree on design principles, the challenge is to apply them creatively to obtain a thought-out design. In today's most accurate machines, advanced techniques are applied for compensation of e.g. residual geometric errors, errors caused by machine dynamics, or thermo-mechanically induced errors. Future developments in Precision Engineering require nanometre- or even subnanometre positioning- and measuring accuracy, demanding new design concepts with integrated control and error compensation systems.

Keywords: Design principles and features, predictive design, accuracy, repeatability, reproducibility.

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1. Introduction

Currently, many activities employed in industry and institutes are aimed at creating high precision products and involve high precision processing. The manufacturing of these products demands a highly specialised science called Precision Engineering, which is based on the following disciplines:

- Design for Precision
- Optical and Mechanical Metrology
- Precision Manufacturing

'Design for Precision' here is meant as total design including materials, mechanics, electronics, control, thermo-mechanics, dynamics and software. It may be indicated as high precision mechatronic design. Design for higher precision is becoming more and more important due to the rapidly increasing need for high accuracy machines, instruments and consumer products. [McKeown, 1987], [Evans, 1988], [Gardner, 1991], [Nakazawa, 1994]. Today, this tendency is highly influenced by developments in computer technology, data processing and data storage. This process started in

1958, when the integrated circuit was invented. The need to have more and more transistors on a chip [Hutcherson, 1996] demanded special machines with an extremely low positioning uncertainty of a few nanometres. An example of such a machine is the waferstepper, used to position the image of the IC on the surface of a silicon wafer. Such a machine can be achieved only by highly developed design- and manufacturing technologies. Also the increasing need for high density optical recording systems (DVD), and as a result for optical disk mastering systems, asks for advanced machines with nanometre uncertainty. The parts used in these machines, like bearings, drives and beam shaping optics, have to be manufactured to submicron accuracy. For the manufacturing process, machines with submicron even down to nanometre accuracy have to be developed.

In Metrology, the technology for high precision measurements is developed e.g. measurement software, error modelling [Soons, 1993], measurement techniques and measurement strategies. To measure parts and products with sufficient accuracy, measuring machines for submicron to nanometre accuracy have to be developed, demanding new design skills since existing design-methods for high precision hardly allow to reach these levels [Teague, 1989, 1997]. Therefore, Metrology as a basic discipline has faced an enormous growth resulting in accurate co-ordinate measuring machines, laser interferometers and nanosensors such as STM and AFM. Additionally much analysis software and software for error compensation was developed and implemented.

Precision Manufacturing concerns the realisation of products with high shape accuracy and surface quality. The accuracy may be at the nanometre level, so both machine design and process behaviour must be well understood as well as the interaction between process and machine, i.e. the interaction between tool and

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Stoffschlüssige Gelenke aus pseudo-elastischen Formgedächtnislegierungen in Pararellrobotern Annika Raatz, 2006 **Proceedings of 5th International Conference on Advanced Manufacturing Engineering and Technologies** Vidosav Majstorovic, Zivana Jakovljevic, 2017-04-22 This book presents the proceedings from the 5th NEWTECH conference Belgrade Serbia 5-9 June 2017 the latest in a series of high level conferences that bring together experts from academia and industry in order to exchange knowledge ideas experiences research results and information in the field of manufacturing The range of topics addressed is wide including for example machine tool research and in machine measurements progress in CAD CAM technologies rapid prototyping and reverse engineering nanomanufacturing advanced material processing functional and protective surfaces and cyber physical and reconfigurable manufacturing systems The book will benefit readers by providing updates on key issues and recent progress in manufacturing engineering and technologies and will aid the transfer of valuable knowledge to the next generation of academics and practitioners It will appeal to all who work or conduct research in this rapidly evolving field Fundamental Principles of Engineering Nanometrology Richard Leach, 2009-09-03 Fundamental Principles of Engineering Nanometrology provides a comprehensive overview of engineering metrology and how it relates to micro and nanotechnology MNT research and manufacturing By combining established knowledge with the latest advances from the field it presents a comprehensive single volume that can be used for professional reference and academic study Provides a basic introduction to measurement and instruments Thoroughly presents numerous measurement techniques from static length and displacement to surface topography mass and force Covers multiple optical surface measuring instruments and related topics interferometry triangulation confocal variable focus and scattering instruments Explains in depth the calibration of surface topography measuring instruments traceability calibration of profile and areal surface texture measuring instruments uncertainties Discusses the material in a way that is comprehensible to even those with only a limited mathematical knowledge **Hybrid Machining** Xichun Luo, Yi Qin, 2018-06-27 Hybrid Machining Theory Methods and Case Studies covers the scientific fundamentals techniques applications and real world descriptions of emerging hybrid machining technology This field is advancing rapidly in industrial and academic contexts creating a great need for the fundamental and technical guidance that this book provides The book includes discussions of basic concepts process design principles standard hybrid machining processes multi scale modeling approaches design on machine metrology and work handling systems Readers interested in manufacturing systems product design or machining technology will find this one stop guide to hybrid machining the ideal reference Includes tables of recommended processing parameters for key engineering materials products for each hybrid machining process Provides case studies covering real industrial applications Explains how to use multiscale modeling for hybrid machining **Micro and Nanomanufacturing** Mark J. Jackson, 2007-06-19 Nanofabrication and nanotechnology present a great challenge to

engineers and researchers as they manipulate atoms and molecules to produce single artifacts and submicron components and systems Micro and Nanomanufacturing provides a comprehensive treatment of established micro and nanofabrication techniques and addresses the needs of practicing manufacturing engineers by applying established and research laboratory manufacturing techniques to a wide variety of materials Engineers seeking more knowledge of how nano and micro devices are designed and fabricated will learn about Manufacturing and fabrication techniques at the micro and nanoscales Using bulk and surface micromachining techniques LiGA and deep x ray lithography to manufacture semiconductors Producing master molds with micromachining The deposition of thin films pulsed water drop machining and nanomachining Mark J Jackson is an Associate Professor in the Department of Mechanical Engineering Technology at Purdue University His current research focuses on understanding the properties of materials in the field of micro scale metal cutting micro and nano abrasive machining and laser micro machining Microengineering of Metals and Ceramics Henry Baltes, Oliver Brand, Gary K. Fedder, Christofer Hierold, Jan G. Korvink, Osamu Tabata, Detlef Löhe, Jürgen Hausselt, 2008-09-26 Microstructures electronics nanotechnology these vast fields of research are growing together as the size gap narrows and many different materials are combined Current research engineering successes and newly commercialized products hint at the immense innovative potentials and future applications that open up once mankind controls shape and function from the atomic level right up to the visible world without any gaps Continuing from the previous volume authors from three major competence centres for microengineering here cover all aspects of specialized replication techniques and how to employ state of the art technologies for testing and characterizing micro scale components and illustrate quality control aspects and strategies for automation of production procedures in view of future industrial production and commercialisation *Applied Mechanics, Mechatronics And Intelligent Systems - Proceedings Of The 2015 International Conference (Ammis2015)* Shihong Qin, Xiaolong Li, 2015-12-08 This book consists of one hundred and twenty five selected papers presented at the 2015 International Conference on Applied Mechanics Mechatronics and Intelligent Systems AMMIS2015 which was held in Nanjing China during June 19 20 2015 AMMIS2015 focuses on seven main areas namely applied mechanics control and automation intelligent systems computer technology electronics engineering electrical engineering and materials science and technology Experts in this field from all over the world contributed to the collection of research results and development activities AMMIS2015 provides an excellent international exchange platform for researchers to share their development works and results in these areas All papers selected for this proceeding were subjected to a rigorous peer review process **North American Science Symposium**, 1999 *Proceedings RMRS.*, 1998 *Mechanics And Materials Science - Proceedings Of The 2016 International Conference (Mms2016)* Chin-wang Tao, 2017-09-25 The 2016 International Conference on Mechanics and Materials Science MMS2016 was held in Guangzhou China on October 15 16 2016 Aimed at providing an excellent international academic forum for all the researchers and practitioners the conference attracted a wide

spread participation among all over the universities and research institutes MMS2016 features unique mixed topics of Mechatronics and Automation Materials Science and Engineering Materials Properties Measuring Methods and Applications This volume consists of 159 peer reviewed articles by local and foreign eminent scholars which cover the frontiers and hot topics in the relevant areas Advances in Mechanical and Power Engineering Holm Altenbach,Alexander H.-D. Cheng,Xiao-Wei Gao,Andrii Kostikov,Wladyslaw Kryllowicz,Piotr Lampart,Viktor Popov,Andrii Rusanov,Stavros Syngellakis,2022-11-25 This book covers theoretical and experimental findings at the interface between fluid mechanics heat transfer and energy technologies It reports on the development and improvement of numerical methods and intelligent technologies for a wide range of applications in mechanical power and materials engineering It reports on solutions to modern fluid mechanics and heat transfer problems on strategies for studying and improving the dynamics and durability of power equipment discussing important issues relating to energy saving and environmental safety Gathering selected contributions to the XIV International Conference on Advanced Mechanical and Power Engineering CAMPE 2021 held online on October 18 21 2021 from Kharkiv Ukraine this book offers a timely update and extensive information for both researchers and professionals in the field of mechanical and power engineering *Integrated Computer Technologies in Mechanical Engineering - 2020* Mykola Nechyporuk,Vladimir Pavlikov,Dmitriy Kritskiy,2021-01-18 This book addresses conference topics such as information technology in the design and manufacture of engines information technology in the creation of rocket space systems aerospace engineering transport systems and logistics big data and data science nano modeling artificial intelligence and smart systems networks and communication cyber physical systems and IoE and software engineering and IT infrastructure The International Scientific and Technical Conference Integrated Computer Technologies in Mechanical Engineering Synergetic Engineering ICTM was formed to bring together outstanding researchers and practitioners in the field of information technology and whose work involves the design and manufacture of engines creation of rocket space systems and aerospace engineering from all over the world to share their experiences and expertise It was established by the National Aerospace University Kharkiv Aviation Institute The ICTM 2020 conference was held in Kharkiv Ukraine on October 28 30 2020 Towards Synthesis of Micro-/Nano-systems Fumihiko Kimura,Kenichiro Horio,2006-10-19 At the beginning of the 21st century manufacturing industry is faced with new challenges stemming from globalization and the need for environmental sustainability The progress of micro nano technology means that precision engineering is now considered to be one of the core disciplines necessary for coping with the sometimes severe requirements of new product and system development From basic research to practical applications advanced process technological methods for the design and synthesis of micro nano systems are becoming more and more important This collection of papers includes high quality papers for industrial and scientific sources discusses leading edge technologies and forecasts future trends Topics covered include but are not limited to advanced manufacturing systems ultra precision and micro machining nanotechnology for

fabrication and measurement rapid prototyping and production technology planning and scheduling for production and CAD CAE CAM

Flexible Robotics Mathieu Grossard, Nicolas Chaillet, Stephane Regnier, 2013-08-05 The objective of this book is to provide those interested in the field of flexible robotics with an overview of several scientific and technological advances in the practical field of robotic manipulation The different chapters examine various stages that involve a number of robotic devices particularly those designed for manipulation tasks characterized by mechanical flexibility Chapter 1 deals with the general context surrounding the design of functionally integrated microgripping systems Chapter 2 focuses on the dual notations of modal commandability and observability which play a significant role in the control authority of vibratory modes that are significant for control issues Chapter 3 presents different modeling tools that allow the simultaneous use of energy and system structuring notations Chapter 4 discusses two sensorless methods that could be used for manipulation in confined or congested environments Chapter 5 analyzes several appropriate approaches for responding to the specific needs required by versatile prehension tasks and dexterous manipulation After a classification of compliant tactile sensors focusing on dexterous manipulation Chapter 6 discusses the development of a complying triaxial force sensor based on piezoresistive technology Chapter 7 deals with the constraints imposed by submicrometric precision in robotic manipulation Chapter 8 presents the essential stages of the modeling identification and analysis of control laws in the context of serial manipulator robots with flexible articulations Chapter 9 provides an overview of models for deformable body manipulators Finally Chapter 10 presents a set of contributions that have been made with regard to the development of methodologies for identification and control of flexible manipulators based on experimental data Contents 1 Design of Integrated Flexible Structures for Micromanipulation Mathieu Grossard Mehdi Boukallel St phane R gnier and Nicolas Chaillet 2 Flexible Structures Representation and Notable Properties in Control Mathieu Grossard Arnaud Hubert St phane R gnier and Nicolas Chaillet 3 Structured Energy Approach for the Modeling of Flexible Structures Nandish R Calchand Arnaud Hubert Yann Le Gorrec and Hector Ramirez Estay 4 Open Loop Control Approaches to Compliant Micromanipulators Yassine Haddab Vincent Chalvet and Micky Rakotondrabe 5 Mechanical Flexibility and the Design of Versatile and Dexterous Grippers Javier Martin Amezcaga and Mathieu Grossard 6 Flexible Tactile Sensors for Multidigital Dexterous In hand Manipulation Mehdi Boukallel Hanna Yousef Christelle Godin and Caroline Coutier 7 Flexures for High Precision Manipulation Robots Reymond Clavel Simon Henein and Murielle Richard 8 Modeling and Motion Control of Serial Robots with Flexible Joints Maria Makarov and Mathieu Grossard 9 Dynamic Modeling of Deformable Manipulators Fr d ric Boyer and Ayman Belkhir 10 Robust Control of Robotic Manipulators with Structural Flexibilities Houssein Halalchi Lo c Cuvillon Guillaume Merc re and Edouard Laroche About the Authors Mathieu Grossard CEA LIST Gif sur Yvette France Nicolas Chaillet FEMTO ST Besan on France St phane R gnier ISIR UPMC Paris France

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