LASER METROLOGY AND MACHINE PERFORMANCE VI

WITPRESS

WIT Press publishes leading books in Science and Technology.

Visit our website for new and current list of titles.

www.witpress.com

WITeLibrary

Making the latest research accessible, the WIT electronic-library features papers presented at Wessex Institute of Technology's prestigious international conferences. To access the library and view abstracts free of charge please visit www.witpress.com

SIXTH INTERNATIONAL CONFERENCE ON LASER METROLOGY, MACHINE TOOL, CMM AND ROBOT PERFORMANCE

LAMDAMAP 2003

CONFERENCE CHAIRMAN

Professor Derek Ford

Director, Centre for Precision Technologies University of Huddersfield, UK

ORGANISING COMMITTEE

Dr Robert Angus Professor Y Kakino

NPL, UK Kyoto University, Japan

Dr O Beltrami Dr W Knapp

S.T.A.N.I M.U.C., Italy
Dr Justin Burrows

Professor Jean-Pierre Kruth

Rolls-Royce plc, UK Katholieke Universiteit Leuven, Belgium

Professor Kai Cheng Mr Philip Lodge

Leeds Metropolitan University, UK Heidenhain (GB) Ltd

Dr Vic Chiles Mr Leonard March

Northumbria University, UK Kistler Instruments Ltd, UK

Mr Nigel Cross Mr Alan Myers

NPL, UK University of Huddersfield, UK

Professor S Dong Mrs Helene D Pickles

Harbin Institute, China University of Huddersfield, UK

Harbin Institute, ChinaUniversity of Huddersfield, UKDr A DonmezDr Crinela Pislaru

NIST, USA University of Huddersfield, UK
Mr R Fergusson-Kelly Mr Derek Rimmer

Renishaw plc, UK Newall Measurement Systems Ltd

Professor Alistair Forbes Dr H Schwenke

NPL, UKPTB, GermanyProfessor Adolf FrankProfessor Paul ScottUniversity of Graz, AustriaTaylor Hobson, UKMr Robert FraserProf Paul Shore

University of Newcastle upon Tyne, UK

Mr Malcolm Gull

ARE LIKE

Cranfield University, UK

Dr Graham Smith

AWE, UK

Dr Martyn Hill

University of Southampton, UK

Professor Tony Hope

Southampton Institute, UK

Mr Malcolm Smith

Heidenhain (GB) Ltd

Professor T R Thomas

Professor Tony Hope Professor T R Thomas

Southampton Institute, UK Chalmers University, Sweden

Dr Kyle C Jiang Dr Qing Ping Yang

Dr Kyle C Jiang Dr Qing Ping Yang
University of Birmingham, UK Brunel University, UK

Organised by:



LASER METROLOGY AND MACHINE PERFORMANCE VI

Editor

D. G. Ford



Professor Derek Ford

Director, Centre for Precision Technologies University of Huddersfield, UK

Published by

WIT Press

Ashurst Lodge, Ashurst, Southampton, SO40 7AA, UK Tel: 44 (0) 238 029 3223; Fax: 44 (0) 238 029 2853 E-Mail: witpress@witpress.com http://www.witpress.com

For USA, Canada and Mexico

Computational Mechanics Inc

25 Bridge Street, Billerica, MA 01821, USA Tel: 978 667 5841; Fax: 978 667 7582 E-Mail: infousa@witpress.com http://www.witpress.com

British Library Cataloguing-in-Publication Data

A Catalogue record for this book is available from the British Library

ISBN: 1-85312-990-9

Library of Congress Catalog Card Number: 2002112345

The texts of the papers in this volume were set individually by the authors or under their supervision. Only minor corrections to the text may have been carried out by the publisher.

No responsibility is assumed by the Publisher, the Editors and Authors for any injury and/ or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein.

© WIT Press 2003

Printed and bound in Great Britain by Bookcraft Ltd.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the Publisher.

PREFACE

This book contains the papers presented at the Sixth International Conference and Exhibition on Laser Metrology, CMM and Machine Tool Performance (LAMDAMAP 2003) that was organised by the University of Huddersfield.

The aim of the Conference was to present the latest technology and techniques for assessing the performance of machine tools and measuring machines. The Conference also aimed to promote collaboration between researchers, designers, machine builders and end users. Work on the enhancement of machine performance along with the latest developments in the field of calibration, certification and standardisation was also presented. The Conference is one of the few where the technologies associated with manufacturing and those associated with metrology overlap to such an extent.

This book contains the invited contributions of four world-class experts. They are: Sir David McMurtry (Chairman & Chief Executive, Renishaw plc); Dr Norbert Hennes (Managing Director, DS Technologies), Professor Brian Rowe (Director of Advanced Manufacturing Lab, Liverpool John Moores University) and Professor Derek Ford (Director, CPT, University of Huddersfield). Their expertise covers the latest developments in probing techniques for CMMs, machine tool design, precision grinding and machine tool performance.

We are indebted to the organisations that have provided sponsorship for this event, in particular to Jarvis plc, our main industrial sponsor. Thanks must also go to all members of the organising committee for their invaluable help and support during the past two years in the formulation, organisation and promotion of this Conference.

PROFESSOR D. G. FORD

Conference Chairman University of Huddersfield July 2003

CONTENTS

Section 1: Machine Tool Machining Performance

Energy and temperature analysis in grinding W.B. Rowe, M.N. Morgan, A. Batako & T. Jin	3
Milling machine tool stability and performance <i>P. Bach</i>	25
Ultra-high speed turning on a vertical machining centre of aerospace aluminium alloys G.T. Smith, G. Littlefair, J.E. Wyatt, J.T. Berry, M.J. Hills & J. Loughlin	35
Investigation of the cutting force coefficients in ball-end milling XW. Liu, K. Cheng, D. Webb, A.P. Longstaff, M.H. Widiyarto, XQ. Jiang, L. Blunt & D.G. Ford	45
Difficulties in characterising roll surfaces T.E. Warrender, D.K. Aspinwall, R.C. Dewes, J.M.T. Simao, E.M. Aspinwall & G. Scamans	55
High-precision automated polishing of engineering components R. Freeman, R. Morton & A. Arthur	65
Section 2: Metrology Applications	
Metrology for parallel kinematic machine tools (PKM) W. Knapp	77
UNISQUARE, a new device to measure the geometric errors of parallel kinematics A. Frank & J. Stoeger	89

Behaviour and accuracy specification – study on an LED-CMOS camera 3D measuring system <i>JP. Kruth, L. Zhou & P. Vanherck</i>	97
Surface analysis techniques to optimise the performance of CNC machine tools <i>XQ. Jiang & L. Blunt</i>	107
Section 3: CMM Inspection and Volumetric Performance	
Inspection of large CMMs by sequential multi-lateration using a single laser tracker <i>K. Wendt, H. Schwenke, W. Bösemann & M. Dauke</i>	121
Investigating the volumetric performance of multi-axis measurement arms J. Singh, M. Hughes & J.N. Petzing	131
Volumetric positioning accuracy of a vertical machining center equipped with linear motor drives (evaluated by the laser vector method) O. Svoboda	141
Section 4: Tool Path Generation, Algorithms and Drives	
Curve fitting with arc splines for NC toolpath generation S.Li, Y. Dai & M. Zhang	153
Identification of modal parameters affecting the dynamic performance of CNC machine tools <i>C. Pislaru, D.G. Ford & J.M. Freeman</i>	161
Modelling and simulation of the turning process A.A. Abdul-Ameer, A. Farshidianfar & M. Ebrahimi	171
A servo parameter tuning method for high-speed NC machine tools based on contouring error measurement K. Lee, S. Ibaraki, A. Matsubara, Y. Kakino, Y. Suzuki, S. Arai & J. Braasch	181
Modelling and simulation of a feed drive using the transmission line modelling technique V.Y. Moreno-Castaneda, C. Pislaru, J.M. Freeman & D.G. Ford	193

Section 5: CMM Application

The development of sensors for CMMs Sir David McMurtry	205
Inspection of curvic couplings using a CMM N.B. Orchard	221
Fixture evaluation based on CMM Y. Wang, X. Chen, Q. Liu & N. Gindy	231
Section 6: CMM Analysis and Algorithm Development	
Analysis of linear and angular errors of a small coordinate measuring machine (SCMM) <i>J. Loh, J. McBride, M. Hill & D. Zhang</i>	245
Mating algorithms based on co-ordinate measurements and conclusions to geometrical dimensioning and tolerancing <i>U. Lunze</i>	257
Correctness of free form surface fitting algorithms A.B. Forbes, P.M. Harris & I.M. Smith	263
Form evaluation algorithms in coordinate metrology D. Zhang, M. Hill, J. McBride & J. Loh	273
Section 7: Machine Tool, Elements and Sensors	
Machine tools for future-oriented production N. Hennes	287
Investigating power quality solutions for computer numerical control machine tools <i>B. Damazo, A. Donmez, H. Soons, M. Stephen & C. Thomas</i>	315
Design optimisation of the head of a high-precision optical polishing machine S.M. Barrans, E.M. Ghurbal & R. Freeman	325
Section 8: Gears, Transmissions and Sensors	
Modelling the dynamic behaviour of a ball-screw system taking into account the changing position of the ball-screw nut	337

Measuring and modelling heat transfer and thermal errors on a ballscrew feed drive system <i>S. Fletcher & D.G. Ford</i>	349
Design of flat pad aerostatic bearings with the aid of finite element analysis <i>S.M. Barrans & N. Bhat</i>	361
Worm gear meshing stiffness calculations based on experiments <i>X. Wang & L. Morrish</i>	371
Flaw detection and quantification for ferromagnetic steels using pulsed eddy current techniques and magnetization A. Sophian, G.Y. Tian, D. Taylor & J. Rudlin	381
A review of the fundamentals of the finite element simulation of metal cutting <i>Q. Xu, B. Miller & D.G. Ford</i>	391
Section 9: Machine Tool Performance	
Machine tool performance: past and present research contributions from the Centre for Precision Technologies <i>D.G. Ford</i>	403
Evaluating the structural dynamics of a vertical milling machine <i>M.H.N. Widiyarto, D.G. Ford & C. Pislaru</i>	421
Finite element analysis of the structural dynamics of a vertical milling machine <i>A. Myers, D.G. Ford & Q. Xu</i>	431
Active vibration control of machine tool structures - Part 1: DSP algorithms S. Lockwood, F. Haase & D.G. Ford	441
Active vibration control of machine tool structures - Part 2: An experimental active-vibration control system F. Haase, S. Lockwood & D.G. Ford	451

Section 10: Machine Tool Measurement and Calibration

A theoretical analysis of 4 body diagonal displacement measurement and sequential step diagonal measurement <i>C. Wang & G. Liotto</i>	463
Practical experience of thermal testing with reference to ISO 230 Part 3 A.P. Longstaff, S. Fletcher & D.G. Ford	473
Evaluation of numerically controlled machine tool positioning accuracy S. Ueno & S. Matsumaru	485
Identification method for scale, pitch and yaw deviations with linear measurements Y. Dupont, G.M. Cloutier & J.R.R. Mayer	495
Method for establishing machine tool performance specifications from part tolerance requirements <i>R. Callaghan</i>	507
Six-degree-of-freedom measurement of machine tool thermal deviations caused by linear axis motion <i>N. Imai & S. Shimizu</i>	517
Methodology and simulation of the calibration of a five-axis machine tool link geometry and motion errors using polynomial modelling and a telescoping magnetic ball-bar Y. Abbaszadeh-Mir, J.R.R. Mayer & C. Fortin	527
Section 11: Condition Monitoring and Instrumentation	
Development of VI-based predictive maintenance system S. Qin, L. Bo & B. Tang	547
Opportunities, problems and solutions when instrumenting a machine tool for monitoring of cutting forces and vibrations <i>P. Norman, D. Legge & M. Bäckström</i>	557
A general data logger for the measurement of the dynamics and the parameter estimation of machine tools J.M. Freeman, A.P. Longstaff & D.G. Ford	569

9 1	A. Kennedy & D.G. Ford Index of Authors	589
<u> </u>	From manual grinding to CNC automation – a major step forward for the rod mill	319