16TH CIRP Conference
on Computer Aided Tolerancing

CHARLOTTE, NC USA **JUNE 15-17, 2020**

Conference Program

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Note from the organizer

Dear attendees,

While I am disappointed that we are not able to meet face-to-face here in Charlotte, I am pleased by the continued enthusiasm of the authors and presenters as well as the encouragement and support of the international scientific committee (listed below). We have tried to arrange the schedule so that attendees from all parts of the world can participate, and I hope that you find our conference enjoyable, enlightening, and thought-provoking.

Edward Morse, Conference Chair

Keynote Speakers

Paul Drake is co-founder of MechSigma Consulting, Inc., where he consults and trains in Geometric Dimensioning and Tolerancing (GD&T), tolerance stacks, and Mechanical Tolerancing for Six Sigma.
Prior to this, Paul worked for Raytheon Systems Company (formerly Texas Instruments' Defense Systems and Electronics Group) where he started the Mechanical Tolerancing and Performance Sigma Center for Excellence. Paul serves on several ASME standards committees, and he chairs the Y14/SC5 (GD&T) Committee and is vice-chair of Y14/SC5.2, Certification of GD&T Professionals subcommittee (GDTP). He is co-inventor of three patents relating to mechanical tolerance analysis. He is technical editor/author of the Dimensioning and Tolerancing Handbook (McGraw-Hill). He is a registered Professional Engineer (Texas), has a Bachelor of Mechanical Engineering degree from the Georgia Institute of Technology and a B.A. in Physics from the University of the South.

Iain Macleod is a chartered mechanical engineer who has been providing training and consultancy in Geometrical Tolerancing (GD&T) and Geometrical Product Specification (ISO GPS) for the best part of 20 years.
He was appointed chair of ISO Technical Committee TC 213 (ISO/TC 213) in 2017. This committee is responsible for international standards for dimensional and geometrical product specification and verification (ISO GPS standards). This is a very active committee, with 25 participating countries, and roughly 100 experts from these countries working in over a dozen different Working Groups and Advisory Groups to develop the detailed technical content of these standards.
Iain also chairs a British Standards technical committee TPR/1/8 which is responsible for the principle UK standard for mechanical specification, BS 8888. He has led the work on developing and improving this standard for the last seven years.
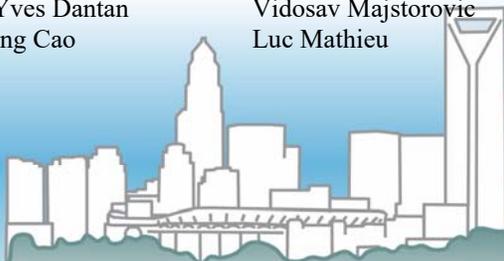
International scientific committee

Gaurav Ameta	Pasquale Franciosa	René Mayer	Vijay Srinivasan
Nabil Anwer	Maurizio Galetto	Giovanni Moroni	Rainer Stark
Andreas Archenti	Salvatore Gerbino	Dimitris Mourtzis	Wahyudin P. Syam
Alex Ballu	Hans Hansen	Stefano Petrò	Denis Teissandier
Alessandro Balsamo	Zbigniew Humienny	Wilma Polini	Guido Tosello
Alain Bernard	Jane X. Jiang	Ahmed J. Qureshi	Michael Walter
Giuliano Bissacco	Richard Leach	Enrico Savio	Hua Wang
Pierre Bourdet	Jean-Marc Linares	Benjamin Schleich	Kristina Wärmefjord
Simone Carmignato	Eric Lutters	Robert Schmitt	Sandro Wartzack
Jean-Yves Dantan	Vidosav Majstorovic	Nicola Senin	Robert G. Wilhelm
Yanlong Cao	Luc Mathieu	Rikard Söderberg	Jose Yague-Fabra

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1. Opening Remarks

   Edward Morse

   University of North Carolina at Charlotte

Keynotes

1. Geometric Dimensioning and Tolerancing – the work of ASME Y14.5

   Paul Drake

   MechSigma Consulting, Inc.

2. Geometrical Product Specification – the work of ISO/TC213

   Iain Macleod

   Iain Macleod Associates Ltd

Session 1   Monday June 15, 2020   1230 UTC

1. Framework for tolerance analysis of over-constrained mechanisms with form defects

   Lazhar HOMRI [a*], Edoh GOKA [a], Pierre BEAUREPAIRE [b], Jean-Yves DANTAN [a]

   [a] LCFC, Arts et Métiers, Université de Lorraine, 4 rue A Fresnel, 57070 METZ, France

   [b] University of Clermont Auvergne, CNRS, SIGMA-Clermont, Institut Pascal, F-63000 Clermont Ferrand, France

2. Investigating the effect of motor micro-stepping on the geometric tolerances of Fused Filament Fabrication printed parts

   Baltej Singh Rupal, Kamalakannan Ramadass, Ahmed Jawad Qureshi [*]

   Additive Design and Manufacturing Systems (ADaMS) Lab, Department of Mechanical Engineering, 9211-116 Street NW, University of Alberta, Edmonton, Alberta, Canada T6G 1H9

3. Effects of contact behaviors on tolerance analysis of mechanism based on skin model shapes and a boundary element method

   Nan Shao, Jianhua Liu, Xiaoyu Ding [*]

   School of Mechanical Engineering, Beijing Institute of Technology, Beijing, 100081, China

4. Integration of surface deformations into polytope-based tolerance analysis: application to an over-constrained mechanism

   Zhiqiang Zhang [a], Jianhua Liu [a*], Nabil Anwer [b], Laurent Pierre [b], Nan Shao [a]

   [a] School of Mechanical Engineering, Beijing Institute of Technology, 100081 Beijing, China

   [b] LURPA, ENS Paris-Saclay, Univ. Paris-Sud, Université Paris-Saclay, 94235 Cachan, France

For all papers: * designates the corresponding author, and
                     bold type designates the presenting author

1. **Tolerance Analysis of Additively Manufactured Non-assembly Mechanisms considering Joint Clearance**

   Paul Schaechtl [*], Martin Hallmann, Benjamin Schleich, Sandro Wartzack

   Engineering Design, Friedrich-Alexander-University Erlangen-Nuremberg (FAU), Martensstrasse 9, 91052 Erlangen, Germany

2. **A statistical approach for tolerancing from design stage to measurements analysis**

   Ambre Diet [ab*], Nicolas Couellan [bc], Xavier Gendre [bd], Julien Martin [a], Jean-Philippe Navarro [a]

   [a] Tolerancing department, Airbus Operations S.A.S, 316 route de Bayonne,31060 Toulouse, France

   [b] Institut de Mathématiques de Toulouse UMR 5219, Université de Toulouse, 31062 Toulouse, France

   [c] ENAC, Université de Toulouse, 7 avenue Édouard Belin, 31400 Toulouse, France

   [d] ISAE-SUPAERO, Universite´ de Toulouse, 10 avenue Édouard Belin, 31055 Toulouse, France

3. **Constructive statistics and virtual capture zones: A novel math model for CMM metrology**

   Nathan J. Kalish [a], Joseph K. Davidson [b*], Jami J. Shah [c]

   [a] Northrop Grumman Corporation, Chandler AZ 85248, USA

   [b] Department of Mechanical and Aerospace Engineering, Arizona State University, Tempe AZ 85287, USA

   [c] Department of Mechanical and Aerospace Engineering, The Ohio State University, Columbus OH 43210, USA

4. **Statistical Analysis of Contact Stiffness for Shaft-Bearing Assembly with Tolerancing and Fit**

   Jhy-Cherng Tsai [a*], Tzu-Ting Chou [a], Che-Kang Chang [b]

   [a] Department of Mechanical Engineering, National Chunghsing University, Taichung 40227, TAIWAN

   [b] Hiwin Technologies Co. Ltd., Taichung 40852, TAIWAN

5. **Tolerance & Time margin**

   Jean-Yves DANTAN [*], Alain ETIENNE, Jelena PETRONIJEVIC, Ali SIADAT

   LCFC, Arts et Métiers, Université de Lorraine, 4 rue A Fresnel, 57070 METZ, FRANCE

Session 3   Monday June 15, 2020   1500 UTC

1. **An Automated Method for Assembly Tolerance Analysis**

   Yuguang Wu [*]

   School of Mechanical Engineering, Hangzhou Dianzi University, Hangzhou 310018, China

2. **Virtual In-line Inspection for Function Verification in Serial Production by means of Artificial Intelligence**

   Raphael Wagner [*], Jakob Fischer, **Daniel Gauder**, Benjamin Haefner, Gisela Lanza

   wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany

3. **Decision support tool for clearance management in a conceptual design context**

   Philippe Serré [*], Mireille Moinet, Jean-François Rameau

   Laboratoire Quartz, 3 rue Fernand Hainaut, 93400 Saint-Ouen, France

4. Theoretical Analysis of Assembly Variation by Positioning between Two Parts using a Round Pin and a Diamond Pin

Shinya SUZUKI [a*], Tohru KANADA [b]

a National Institute of Technology (KOSEN), Nagano College, Tokuma 716 Nagano, JAPAN

b Kanto Gakuin University, Yokohama 236-8501, JAPAN

5. Tolerance analysis of an assembly by considering part deformation

Zhi Junnan [ab], Cao Yanlong [ab*], Liu Fan [b], Liu Ting [b], Yang Jiangxin [bc]

a State Key Laboratory of Fluid Power and Mechatronic Systems, college of Mechanical Engineering, Zhejiang University, Hangzhou, 310027, China

b Key Laboratory of Advanced Manufacturing Technology of Zhejiang Province, college of Mechanical Engineering, Zhejiang University, Hangzhou, 310027, China

c Key Laboratory of Digital Design and Intelligent Manufacturing for Creative Cultural Products of Zhejiang Province, Lishui, 323000, China

Session 4   Tuesday June 16, 2020   1030 UTC

1. How to consider Over-constrained Assemblies with Gaps in Tolerance-Cost Optimization?

Martin Hallmann *, Benjamin Schleich, Sandro Wartzack

Engineering Design, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Martensstrasse 9, 91058 Erlangen, Germany

2. Geometrical Variation Mode Effect Analysis (GVMEA) for Split Lines

Kristina Wärmefjord*, Rikard Söderberg, Andreas Dagman, Lars Lindkvist

Chalmers University of Technology, Department of Industrial and Materials Science, SE 412-96 Gothenburg, Sweden

3. Comparison between two numerical tools for geometrical deviation analysis in composite assemblies

Andrea Corrado [a], **Wilma Polini** [a*], Giovanni Moroni [b]

a Department of Civil and Mechanical Engineering, Università degli Studi di Cassino e del Lazio Meridionale, via G. di Biasio 43, 03043 Cassino, Italy

b Mechanical Engineering Department, Politecnico di Milano, via La Masa 1, 20156 Milano, Italy

4. Simulating the Respect of a Functional Condition in a Mechanical System with Mobilities

Denis Teissandier [a], Vincent Delos [b], **Sonia C. García** [a*]

a Univ. Bordeaux, I2M, UMR 5295, F-33400 Talence, France

b CNRS, I2M, UMR 5295, F-33400 Talence, France

5. Tolerance analysis tools for fixture design: a comparison

Andrea Corrado, **Wilma Polini** *

Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, via G. di Biasio 43, 03043 Cassino, Italy

1. GPS training tool

Zbigniew Humienny [a*], Marcin Berta [b]

[a] *Institute of Machine Design Fundamentals, Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland*

[b] *DMG MORI Polska Sp. z o.o., Fabryczna 7, 63-300 Pleszew, Poland*

2. Geometrical Product Specifications (GPS): A Review of Teaching Approaches

Peter Gust, **Alina Sersch** [*]

Engineering Design, University of Wuppertal, Gaußstr.20, 42119 Wuppertal, Germany

3. Introduction of a maturity model for the assessment of the integration of the GPS system in companies

Juliane Schuldt, Robert Hofmann [*], Sophie Gröger

TU Chemnitz Faculty of Mechanical Engineering, Professorship of Production Measuring Technology, Reichenhainer Str. 70, 09126 Chemnitz, Germany

4. The Computer Vision-based Tolerancing Callout Detection Model

Xin Deng [a], Tukun Li [bc], Yuanping Xu [b*], Yanlong Cao [c], Chao Kong [c] and Errui Zhang [d]

[a] *School of Software Engineering, Chengdu University of Information Technology, Chengdu, China*

[b] *EPSRC Future Advanced Metrology Hub, Centre for Precision Technologies, School of Computing and Engineering, University of Huddersfield, Huddersfield, HD1 3DH, UK*

[c] *Shandong Industrial Technology Research Institute of Zhejiang University, Shandong, 277500, China*

[d] *College of Engineering and Computer Science, Australia National University, Canberra, ACT 2600, Australia*

Session 6   Tuesday June 16, 2020   1330 UTC

1. Default filtration for datum cylinders: a proposal

Daniel E. Wilcox [*]

Hexagon Manufacturing Intelligence, 170 S 1200 E #120, Lehi UT 84043, USA

2. On Riemann sums and integrals for association operations in ISO Geometrical Product Specifications standards

Craig Shakarji [a*], Vijay Srinivasan [b]

[a] *NIST, Physical Measurement Laboratory, 100 Bureau Dr, Gaithersburg, MD 20899*

[b] *NIST, Engineering Laboratory, 100 Bureau Dr, Gaithersburg, MD 20899*

3. Toward a Mathematical Definition of Reconstruction Operation for ISO GPS Standards

Yifan Qie [a*], Nabil Anwer [a], Paul J. Scott [b], Jane X. Jiang [b], Vijay Srinivasan [c]

[a] *Université Paris-Saclay, ENS Paris-Saclay, LURPA, 94235, Cachan, France.*

[b] *University of Huddersfield, Huddersfield, U.K.*

[c] *National Institute of Standards and Technology, Gaithersburg, MD, U.S.A.*

4. Defining and Controlling Variation of Highly-Interrupted Collected Features

Bryan Fischer [a], Edward Morse [b*]

[a] *TDP360,21370 SW Langer Farms Pkwy, Suite 142, Box 140, Sherwood, OR 97140 USA*

[b] *UNC Charlotte 9201 University City Blvd, Charlotte, NC 28223 USA*

1. **Robustness of geometric verification by segmentation-free X-ray computed tomography**

Stefano Petrò [*], Giovanni Moroni

Department of Mechanical Engineering, Politecnico di Milano, Via Giuseppe La Masa, 20156 Milano, Italy

2. **Geometric Tolerance Characterization of Laser Powder Bed Fusion Processes Based on Skin Model Shapes**

Baltej Singh Rupal [abc], Nabil Anwer [b], Marc Secanell [c], Ahmed Jawad Qureshi [a*]

[a] Additive Design and Manufacturing Systems (ADaMS) Lab, Department of Mechanical Engineering, University of Alberta, Edmonton, Canada

b Université Paris-Saclay, ENS Paris-Saclay, LURPA, 94235, Cachan, France

[c] Energy Systems Design Lab (ESDL), University of Alberta, Department of Mechanical Engineering, University of Alberta, Edmonton, Canada

3. **On-Machine Measuring Method for the Reconstruction of Additively Manufactured Near-Net Shaped Parts**

Christina Haeussinger [a*], Laura Brunner, Alex Martiner, Robin Kleinwort [a], Michael F. Zaeh [a]

[a] Technical University of Munich, Department of Mechanical Engineering, Institute for Machine Tools and Industrial Management, Boltzmannstr. 15, 85748 Garching, Germany

4. **Exploring Registration of Optical, CMM and XCT for Verification of Supplemental Surfaces to Define AM Lattices: Application to Cylindrical and Spherical Surfaces**

Maxwell Praniewicz [a*], Jason Fox [b], Gaurav Ameta [c], Felix Kim [b], Paul Witherell [b], Christopher Saldana [a]

[a] George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, 801 Ferst Drive, Atlanta, Georgia 30332

[b] National Institute of Standards and Technology , Gaithersburg, MD 20899

[c] Siemens Corporate Research, Princeton, NJ 08540

5. **Investigation of Light-Induced Surface Roughness in Projection Micro-Stereolithography Additive Manufacturing (PµSLA)**

Khaled G. Mostafa, David S. Nobes, Ahmed Jawad Qureshi [*]

Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, T6G 1H9 Canada

1. **Ontology-based representation of tolerancing and design knowledge for an automated tolerance specification of product concepts**

Stefan Goetz [*], Benjamin Schleich

Engineering Design, Friedrich-Alexander-University Erlangen-Nuremberg (FAU), Martensstrasse 9, 91054 Erlangen, Germany

2. **Skin Model Shapes for multi-stage manufacturing in single-part production**

Robert Hofmann [a*], Sophie Gröger [a], Nabil Anwer [b]

[a] Chemnitz University of Technology, Professorship of Production Measuring Technology, Reichenhainer Straße 70, 09126 Chemnitz, Germany

[b] LURPA, ENS Paris-Saclay, Universite Paris-Sud, Universite Paris-Saclay, 94235, Cachan, France

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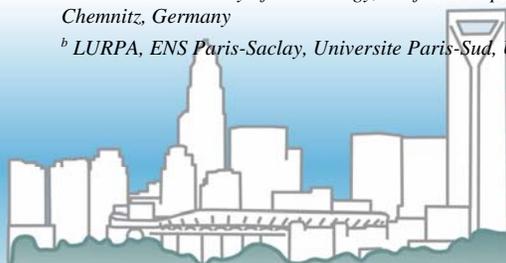
3. Multiphysical tolerance analysis – Assessment technique of the impact of the model parameter imprecision

Jean-Yves DANTAN [a*], Tobias EIFLER [b], Lazhar HOMRI [a]

[a] LCFC, Arts et Métiers, Université de Lorraine, 4 rue A Fresnel, 57070 METZ, FRANCE

[b] Technical University of Denmark (DTU), Kgs. Lyngby, 2800, Denmark

4. An approach for determining the influence of manufacturing process parameters on product quality characteristics

Björn Heling [*], Benjamin Schleich, Sandro Wartzack

Engineering Design, Friedrich-Alexander-University Erlangen-Nürnberg (FAU), Martensstr. 9, 91058 Erlangen, Germany

Session 9   Wednesday June 17, 2020   1145 UTC

1. Tolerancing from STL data: A Legacy Challenge

Torbjørn Langedahl Leirmo [*], Oleksandr Semeniuta, Kristian Martinsen

Department of Manufacturing and Civil Engineering, Norwegian University of Science and Technology, Teknologivegen 22, 2815 Gjøvik, Norway

2. Generation method of skin model shapes with features of machining marks using dual-tree complex wavelet transform

Akimasa Otsuka*, Naoto Miyoshi, Fusaomi Nagata

Department of Mechanical Engineering, Sanyo-Onoda City University, 1-1-1 Daigaku Dori, Sanyo-Onoda, 7560884, Japan

3. Functional tolerancing of surface texture – a review of existing methods

Johan Berglund [ab*], Rikard Söderberg [a], Kristina Wärmefjord [a], Richard Leach [c], Edward Morse [d]

[a] Chalmers University of Technology, Göteborg, SE-412 96, Sweden

[b] RISE IVF, Box 104, Mölndal, SE-431 22, Sweden

[c] University of Nottingham, Nottingham NG8 1BB, UK

[d] University of North Carolina at Charlotte, 9201 University City Blvd, Charlotte, NC 28223-0001,USA

Conference Closing   Wednesday June 17, 2020   1300 UTC

1. Final Remarks

Edward Morse

University of North Carolina at Charlotte

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