



**Fraunhofer** Institut  
Werkzeugmaschinen  
und Umformtechnik

## **Development Methods and Application Experience of Parallel Kinematics**

The 3<sup>rd</sup> Chemnitz  
Parallel Kinematics Seminar  
2002 Parallel Kinematic Machines  
International Conference  
2<sup>nd</sup> NCG Application Conference  
on Parallel Kinematic Machines

**PKS 2002**  
Parallel Kinematics Seminar  
April 23-25, 2002

## Impressum

### **Development Methods and Application Experience of Parallel Kinematics**

The 3<sup>rd</sup> Chemnitz  
Parallel Kinematics Seminar

2002 Parallel Kinematic Machines  
International Conference

2<sup>nd</sup> NCG Application Conference  
on Parallel Kinematic Machines

#### **Herausgeber:**

Prof. Dr.-Ing. habil. Reimund Neugebauer

#### Wichtiger Hinweis:

Das Werk, einschließlich aller seiner Teile, ist urheberrechtlich geschützt. Jede Verwertung außerhalb der engen Grenzen des Urheberrechtsgesetzes ist ohne Zustimmung des Verlages unzulässig und strafbar. Das gilt insbesondere für Vervielfältigungen, Übersetzungen, Mikroverfilmungen und die Einspeicherung und Verarbeitung in elektronischen Systemen.

© 2002

**Fraunhofer Institute for Machine Tools and Forming Technology IWU**

Reichenhainer Straße 88, 09126 Chemnitz, Germany  
e-mail: info@iwu.fraunhofer.de

**Verlag Wissenschaftliche Scripten**

Thurmer Straße 30, 08066 Zwickau, Germany  
e-mail: wiss.scripTEN@t-online.de

ISBN: 3-928921-76-2

# Table of contents

## ***Plenary Papers***

Parallel Kinematic Structures in Manufacturing.....	17
Neugebauer, R.; Harzbecker, C.; Drossel, W.-G.; Stoll, A.; Ihlenfeldt, S.	
The Need for a Systematic Methodology for the Evaluation and Optimal Design of Parallel Manipulators .....	49
Merlet, J.-P.	
Parallel Kinematic Machines in Practice .....	63
Treib, T.	

## ***Development***

Design Issues for Reconfigurable PKMs.....	69
Jovane, F.; Negri, S. P.; Fassi, I.; Molinari Tosatti, L.	
Designing PKMs: Working Volume, Stiffness, Frequencies.....	83
Cobet, M.	
Structure Optimization of Machine Tools with Parallel Kinematics.....	105
Neugebauer, R.; Weidemann, F.	
Contributions to the Algorithm of Plane-Producing Envelope Surfaces by Using Parallel Kinematic Machines Structure and Kinematics .....	119
Orlandea, N. V.	
An Orientational 3-DOF Parallel Mechanism .....	139
Karouia, M.; Hervé, J. M.	
Modelling of a 4-Axis Parallel Machine for Heavy Parts Handling.....	151
Company, O.; Krut, S.; Pierrot, F.	

Advantages of the Modified Euler Angles in the Design and Control of PKMs .....	171
Bonev, I. A.; Zlatanov, D.; Gosselin, C. M.	
The Modeling and Optimization System of Hexapod Layout.....	189
Astanin, V.; Duyunov, A.; Smotritsky, G.; Usov V.	
Task Oriented Multi-Objective-Optimization of Parallel-Kinematics for Machine Tools .....	197
Weck, M.; Giesler, M.	
Optimized Hybrid MachineStructures - A New Development Approach .....	213
Kuhfuss, B.; Schenck, C.	
A Six-leg, Four-DOF Parallel Manipulator .....	227
Wen-jia, C.; Ming-yang, Z.; Ling, Y.	

### ***Components***

An Experience in Design and Development of Joints for Parallel Kinematics Machines.....	243
Annacondia, E.; Aprile, E.; Dotta, A.; Boër, C. R.	
Achieving Technical and Economic Potential with INA Components .....	263
Dürschmied, F.; Hestermann, J.-O.	
Intelligent Strut .....	277
Neugebauer, R.; Drossel, W.-G.; Roscher, H.-J.; Schwaar, M.	
Spherical Joint with Increased Mobility for Octapod .....	285
Valasek, M.; Sulamanidze, D.; Bauma, V.	
Application of the Grid-Bar Device on the Hexaglide.....	295
Weikert, S.; Knapp, W.	

## **Control**

Influence of the Dynamic Stiffness on the Accuracy of PKM.....	313
Pritschow, G.; Eppler, C.; Garber, T.	
Modelling and Control of a Linear Direct Driven Hexapod .....	335
Tönshoff, H. K.; Grendel, H.; Grotjahn, M.	
Concept and Application of a Model-Based Control Input Compensation for Parallel-Kinematic Machine Tools .....	351
Hadorn, M.	
A Feed Rate Optimization Technique for High-Speed CNC Machining with Parallel Manipulators .....	371
Dallefrate, D.; Carpanzano, E.; Molinari Tosatti, L.; Jovane, F.	
Analysis of Backlash Effects on Motion Accuracy of a Novel 3-PRS Mechanism using Forward Kinematics Approach .....	389
Chang, T.-H.; Tsai, Y.-J.; Tasi, M.-S.	
Dynamic Modelling of Plane Parallel Robots for Control Purposes .....	391
Hesselbach, J.; Becker, O.; Krefft, M.; Pietsch, I.; Plitea, N.	
Control and Calibration of Redundantly Actuated Parallel Robots .....	411
Valasek, M.; Belda, K.; Florian, M.	
A Cost-Effective Purely Translational Parallel Robot for Rapid Assembly Tasks .....	429
Bruzzone, L. E.; Molfino, R. M.; Zoppi, M.	

## **Calibration**

Improvement of the Calibration Accuracy by a New Measurement Process .....	443
Neugebauer, R.; Krabbes, M.; Kretzschmar, W.; Schönitz, J.	
The Fixed Point Method for Structure Calibration of Parallel Machine Tools .....	455
Yuan, J.; Wang, Z.; Liu, F.	
Total Self-Calibration of a General Architecture Hexapod Manipulator .....	469
Chiu, Y.-J.; Perng, M.-H.	
Pose Error Characterization and Compensation Strategy for a 3 dof PKM.....	491
Molinari Tosatti, L.; Rebaglia, B.; Bianchi, G.; Fassi, I.; Jovane, F.	
Calibration of Parallel Robots with ROSY .....	493
Beyer, L.; Wulfsberg, J.-P.	
Screw-Theory Based Error Prediction of a Novel Compliant PKM .....	507
Moon, S.-K.; Moon, Y.-M.; Kota, S.	
A Study on the Accuracy of a Novel 4-DOF Hybrid Machine Tool.....	509
Tang, X.; Yin, W.; Wang, J.	

## **Application**

Computer Aided Optimization of the Static and Dynamic Properties of Parallel Kinematics .....	527
Weule, H.; Albers, A.; Haberkern, A.; Neithardt, W.; Emmrich, D.	
Tricept Applications.....	547
Neumann, K. E.	

<b>A New Parallel Kinematics for High-Speed Machine Tools – Hita STT .....</b>	<b>553</b>
Thurneysen, M.; Schnyder, M.; Clavel, R.; Giovanola, J.	
<b>New Automation Solutions in Aeronautics Through Parallel Kinematic Systems.....</b>	<b>563</b>
Saenz, A. J.; Collado, V.; Gimenez, M.; San Sebastian, I.	
<b>Tripod Machine SKM 400 Design, Calibration and Practical Application .....</b>	<b>579</b>
Schoppe, E.; Pönisch, A.; Maier, V., Puchtler, T. Ihlenfeldt, S.	
<b>TriCenter - A Universal Milling Machine With Hybrid Kinematic.....</b>	<b>595</b>
Gronbach, H.	
<b>CROSS HÜLLER SPECHT Xperimental, a Processing Center with New Hybrid Kinematics.....</b>	<b>609</b>
Stengele, G.	
<b>Application of the Parallel Kinematic Machine Principle in a New Hydraulic Powered, Flexible Bending Machine for Tubes and Profiles .....</b>	<b>629</b>
Neugebauer, R.; Putz, M.; Drossel, W.-G.; Lorenz, U.; Blau, P.	
<b>Modelling of Error Effects on the New Hybrid Kinematic DUMBO-Structure.....</b>	<b>639</b>
Tönshoff, H. K.; Denkena, B.; Günther, G.; Möhring, H.-C.	
<b>A New Hybrid Six-Axis-Machine for Efficient Cutting Convex Glass Panels .....</b>	<b>655</b>
Hesselbach, J.; Soetebier, S.; Frindt, M.; Plitea, N.	
<b>Mechatronic Design, Experimental Property Analysis and Machining Strategies for a 5-Strut-PKM .....</b>	<b>671</b>
Schwaar, M.; Jaehnert, T.; Ihlenfeldt, S.	
<b>PKM Concept for Reconfigurable Machine Tools.....</b>	<b>683</b>
Wurst, K.-H.; Peting, U.	

Workspace-Optimized Parallel Robot for Placing Tasks .....697

Hesselbach, J.; Helm, M. B.; Soetebier, S.

Investigation of Truss Structures as Light Weight Elements  
for the Use in Parallel Kinematic Machines .....715

Heisel, U.; Maier, W.

Design and Optimum Operation of a Reconfigurable  
Planar Gough-Stewart Machining Platform.....729

Du Plessis, L. J.; Snyman, J. A.

### ***Application Experience***

#### ***2<sup>nd</sup> NCG Application Conference on Parallel Kinematic Machines***

Requirements for Parallel Kinematics for Powertrain  
Manufacturing in the Automotive Industry.....753

Hertel, A.

ECOSPEED – An Innovative Machinery Concept for  
High-Performance 5-Axis-Machining of Large Structural  
Components in Aircraft Engineering.....763

Hennes, N.

Quicker Success with Hybrid Kinematics »ECOSPEED«.....775

Lilla, A.

Modelling and Simulating the Dynamic Behaviour of a  
High Speed Machine Tool .....785

Vareilles, E.; Fioroni, C.; Ghassempouri, M.

Application Experience with a Hexapod Machine Tool  
for Machining Complex Aerospace Parts .....807

Weck, M.; Staimer, D.

An Evaluation of the Machining Performance of the  
Giddings and Lewis Variax for Hard and Difficult Materials .....817

Webb, P.; Geldart, M.; Gindy, N.

Interaction Between Machine Tool and Process – Modelling,  
Simulation and Identification of Milling Operations on  
Hexapod 6X HEXA .....833  
Neugebauer, R.; Leopold, J.; Hoyer, K.; Stoll, A.; Kolbig, S.

PEGASUS – Incorporating PKM into Woodworking .....843  
Czwielong, T.; Zarske, W.

System Comparison: 5-Axis High Speed Cutting Machines  
vs. Parallel Kinematic Machine .....857  
Treib, T.

**Poster**

Synthesis of the Equipment on the Base of  
Parallel Kinematic Mechanism .....861  
Podzorov, P. V.; Bushuev, V. V.

Optimizing a Three-Axes Machine-Tool with  
Parallel Kinematic Structure.....883  
Bleicher, F.

Some Novel Minor-Mobility Parallel Mechanisms .....895  
Huang, Z.; Li, Q. C.

Global Kinetostatic Analysis of Parallel Kinematic Machines .....907  
Xi, F.; Zhang, D.; Mechefske, C. M.

A Comparison Study on Tripod Units for Machine Tools .....923  
Xi, F.; Zhang, D.; Xu, Z.; Mechefske, C. M.

Design Optimization of Parallel Kinematic Toolheads  
with Genetic Algorithms .....941  
Zhang, D.; Xu, Z.; Mechefske, C. M.; Xi, F.

Application of Parallel Kinematics Machines for Active Vibration Isolation and Pointing of High-Precision Large Deployable Space Structures (HLDSS) .....	957
Sayapin, S. N.	
Methodological Aspects on Pose Error Characterization and Calibration of Parallel Kinematic Machines (PKM). Proposal of a Structured Self-Calibration Procedure. ....	963
Cenati, C.; Cibien, M.; Molinari Tosatti, L.; Rebaglia, B.	
Virtual Reality as an Inherent Part of the Development and Testing of Machine Tools with Parallel Kinematics .....	983
Weidlich, D.; Kolbig, S.; Polzin, T.	
Redundantly Actuated Parallel Structures – Principle, Examples, Advantages .....	993
Valasek, M.; Bauma, V.; Sika, Z.; Vampola, T.	
Geometric Error Effects on the Performances of a Parallel Wrist.....	1011
Di Gregorio, R.; Parenti-Castelli, V.	
Authors index.....	1025