Program of

The Eleventh International Symposium on Magnetic Bearings

ISMB-11

Nara Prefectural New Public Hall

Nara, JAPAN

Aug. 26 – 29, 2008
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Preface

Welcome to the Eleventh International Symposium on Magnetic Bearings, ISMB-11. For the first time, it is taking place in Nara, an ancient capital of Japan, which is known as the home of Japanese history and culture.

This symposium started in Zürich, Switzerland in 1988 (Chairperson: G. Schweitzer). The second was held in Tokyo, Japan in 1990 (Chairperson: T. Higuchi). The third was held in Alexandria, USA in 1992 (Chairperson: P. Allaire). The fourth was held again in Zürich, Switzerland in 1994 (Chairperson: G. Schweitzer). The fifth symposium was held in Kanazawa, Japan in 1996 (Chairperson: F. Matsumura). The sixth was held in Boston, USA in 1998 (Chairpersons: D. Trumper & P. Allaire). The seventh was held again in Zürich, Switzerland in 2000 (Chairperson: G. Schweitzer). The eighth was held in Mito, Japan in 2002 (Chairperson: Y. Okada). The ninth was held in Lexington, USA in 2004 (Chairpersons: S. Stephens & D. Trumper). The tenth was held in Martigny, Switzerland in 2006 (Chairpersons: H. Bleuler & G. Genta). The symposium has developed into a very attractive and genuine international event for the advancement of magnetic bearing technology. ISMB-11 will be a good opportunity to see the new directions of magnetic bearing technology.

The technical program includes just 100 papers, with 71 papers from 17 countries and 29 papers from Japan. It covers wide range of technical areas that are indicated by the session topics:

- Modeling and identification
- Components
- Touch Down Bearing
- Self-bearing (Bearingless) Motor
- Industrialization
- Magnetic Suspension
- Micro Bearing
- Safety and Reliability Aspects
- Related New Fields
- Control
- Sensors, Actuators, Controllers
- Magnetic Actuator
- Self-Sensing (Sensorless) Techniques
- Contact-Free Bearings for Flywheel
- Applications
- Ultra High Speed Bearing
- Passive Suspension

In addition, there are two keynote addresses and a technical exhibition.

We wish all those attending ISMB-11 to have fruitful experiences through participation in the technical sessions and the other activities such as appreciating "Noh", a traditional Japanese masked dance-drama, and visiting "Horyuji Temple", the oldest wooden building existing in the world.

It is our pleasure to thank the members of the International Advisory Committee, International Steering Committee, and Organizing Committee for their sincere support and time-consuming tasks.

Thanks are also given to all the supporting organization and all the collaborating societies.

We wish you a fruitful and exciting stay in Nara, and we hope that you will enjoy its unique atmosphere and the traditional cultures.

Kenzo NONAMI
Co-Chairperson of the Eleventh International Symposium on Magnetic Bearings

Takeshi MIZUNO
Co-Chairperson of the Eleventh International Symposium on Magnetic Bearings
The Main Topics of the Symposium

- Active magnetic bearings
- Passive magnetic bearings
- Electrodynamic bearings
- Sensors, actuators, controllers for magnetic bearings
- Touch down bearings
- Industrialization
- Safety and reliability aspects
- Components and materials
- Low loss magnetic bearings
- Modeling and identification
- Self-bearing (bearingless) motors
- Self-sensing (sensorless) techniques
- Contact-free bearings for flywheels
- Magnetic suspensions
- Superconductors, diamagnetic bearings
- Micro bearings, ultra high speed bearings
- Other related new fields

Co-Sponsors

- Dynamics, Measurements and Control Division of Japan Society of Mechanical Engineers
- The Japan Society of Applied Electromagnetics and Mechanics
- Nara Convention Bureau
- Electro-Mechanic Technology Advancing Foundations
- Suzuki Foundation
- Commemorative Organization for the Japan World Exhibition ‘70

Collaborating Societies

- The Institute of Electrical Engineers of Japan
- The institute of Systems, Control and Information Engineers
- The Japan Society for Precision Engineering
- The Society of Instrument and Control Engineers
International Advisory Committee

- Allaire, P.; University of Virginia, USA
- Bleuler, H.; EPFL Lausanne, SWITZERLAND
- Genta, G.; Politecnico di Torino, ITALY
- Higuchi, T.; University of Tokyo, JAPAN
- Larsonneur, R.; MECOS Traxler AG, SWITZERLAND
- Maslen, E.; University of Virginia, USA
- Mizuno, T.; Saitama University, JAPAN (Co-Chair)
- Nonami, K.; Chiba University, JAPAN (Co-Chair)
- Okada, Y.; Ibaraki University, JAPAN
- Schmied, J.; Delta JS AG, SWITZERLAND
- Schweitzer, G.; ETH, Zurich, SWITZERLAND
- Stephens, S.; University of Kentucky, USA
- Trumper, D.; MIT, USA
- Ulbrich, H.; Technical University of Munich, GERMANY
- Yu, L.; Xi'an Jiaotong University, CHINA

International Steering Committee

- Amrhein, W.; Johannes Kepler Univ., AUSTRIA
- Blumenstock, K.; NASA Langley, USA
- Brown, G.; NASA Glenn Research Center, USA
- Brunet, M.; Soc. De Mech. Magnet, FRANCE
- Burrows, C.; University of Bath, UK
- Carroll D.; Airex Corporation, USA
- Chiba, A.; Tokyo University of Science, JAPAN
- Eisenhaure, D.; SatCon Technology Corp, USA
- Fujita, M.; Tokyo Institute of Technology, JAPAN
- Hawkins, L.; Calnetix, USA
- Herzog, R.; EIVD Yverdon, SWITZERLAND
- Kasarda, M. E. F.; Virginia Tech, USA
- Kleynhans, G.; MAN Turbo. LTD., SWITZERLAND
- Knospe, C.; University of Virginia, USA
- Komori, M.; Kyushu Institute of Technology, JAPAN
- Kondoleon, A.; Draper Laboratory, USA
- Lee, C. W.; KAIST, KOREA
- Lembke, T., Uppsala University, SWEDEN
- Matsushita, O.; National Defense Academy, JAPAN
- Nakajima, A.; JAXA, JAPAN
- Namerikawa, T.; Kanazawa University, JAPAN
- Nordmann, R.; Darmstadt Univ. of Tech., GERMANY
- Oka, K.; Kochi University of Technology, JAPAN
- Roberts, M.; Revolve Mag. Bearings Inc. CANADA
- Sandtner J.; EPFL Lausanne, SWITZERLAND
- Takahata, R.; JTEKT Corp., JAPAN
- Tao, G.; University of Virginia, USA
- Traxler, A.; Mecos Traxler AG SWITZERLAND
- Ueyama, H.; MUTECS Inc., JAPAN

Organizing Committee
- Nonami, K.; Chiba University (Co-Chair)
- Mizuno, T.; Saitama University (Co-Chair)
- Ueno, S.; Ritsumeikan University (Secretariat)
- Komori, M.; Kyushu Institute of Technology (Program chair)
- Takahata, R.; JTEKT Corporation
- Ariga, Y.; Yamagata University
- Inoue, T.; Nagoya University
- Kanebako, H.; MISUZU Industries Corporation
- Kanki, H.; Kobe University
- Saito, O.; IHI, JAPAN
- Shinshi, T.; Tokyo Institute of Technology
- Niino, T.; University of Tokyo
- Chiba, A.; Tokyo University of Science
- Nakajima, A.; JAXA, JAPAN
- Hikihara, T.; Kyoto University
- Hirata, M.; Utsunomiya University
- Fujita, M.; Tokyo Institute of Technology
- Matsushita, O.; National Defense Academy
- Morishita, M.; Toshiba Corporation
- Watanabe, T.; Nihon University
- Oshinoya, Y.; Tokai University
- Oka, K.; Kochi University of Technology
- Namerikawa, T.; Kanazawa University
- Kubota, M.; Central Japan Railway Company
- Takahashi, N.; Hitachi Plant Technologies, Ltd.
- Sakai, S.; Chiba University
- Sugie, T.; Kyoto University
- Kawanishi, M.; Toyota Technological Institute
- Ohashi, S.; Kansai University
- Ohsaki, H.; University of Tokyo
- Ooshima, M.; Tokyo University of Science, Suwa
- Tokimasa, Y.; Mitsubishi Heavy Industries, Ltd.
- Takasaki, M.; Saitama University
Exhibition

The symposium is accompanied by an exhibition. The exhibition is held in Reception Room on the upper floor of the symposium venue. The following companies present their magnetic bearing systems, products and related technologies.

- Cybernet Systems Co., Ltd.
- MTT Corporation
- Yokohama Engineering Service Ltd.
- MUTECS (MECOS)
- S2M-Japan Co., Ltd
- Synchrony Inc.
- Edwards Japan Ltd. (catalog exhibit)

Symposium participants from universities and academia institutes exhibit their own research, developing devices and test rigs in the same room. The exhibition schedule is as follows.

- Aug. 27, 2008: 9:00 – 17:00
- Aug. 28, 2008: 9:00 – 13:00
- Aug. 29, 2008: 9:00 – 16:00

Breaks

Drinks for breaks and lunches are served in the Reception Room, where the symposium exhibition is held. Except for the Reception Room, drinking and eating are strictly prohibited by the symposium venue. Participants cannot bring any drinks and/or foods to Session Rooms / Garden behind the venue. No smoking is allowed inside the venue. “Smoking area” is located around Entrance (outside of the building). To protect the cultural hall and garden, all participants are required to understand and obey these rules.

Social Events

Welcome Reception
18:00 – 19:30, Aug. 26, 2008, at Reception Hall

Japanese Traditional “Noh”
18:00 – 18:30, Aug. 27, 2008, at Room A

Horyuji Temple Tour
13:00 – 17:00, Aug. 28, 2008, pick up in front of Entrance

Banquet
18:00 – 20:00, Aug. 28, 2008
Banquet room YAMATO
Nara Hotel
1096, Takabatake-cho, Nara City, 630-8301, Japan
Phone: +81-742-26-3300
Fax: +81-742-23-5252

Farewell Party
17:00 – 18:30, Aug. 29, 2008, at Reception Hall
Floor Plan

Upper floor

- Room C
- Reception Hall
  - Breaks
  - Lunches
  - Exhibit
  - Welcome Reception
  - Farewell Party

Ground floor

- Room B
- Room A
- Entrance

Key:
- S: Stair
- E: Elevator
- T: Toilet
# Symposium Time Table

**Aug. 26, 2008 (TUE)**

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<th>Event</th>
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<td>17:00 – 18:00</td>
<td>Registration</td>
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<tr>
<td>18:00 –</td>
<td>Welcome Reception</td>
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**Aug. 27, 2008 (WED)**

<table>
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<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:30 – 9:00</td>
<td>Registration</td>
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| 9:00 – 10:00| Welcome Address by Prof. Kenzo Nonami, Chiba University, Japan (Room A)  
Keynote Address: 20 Years ISMB: Then, Now, Future (Room A)  
Prof. Hannes Bleuler, EPFL, Switzerland |
| 10:00 – 10:30 | Break                                                  |
| 10:30 – 12:10| Magnetic Actuators I ........................................14  
Masahide Ooshima, Shyh-Leh Chen  
Sensors, Actuators, Controllers I ......................15  
Josu Jugo, Atsushi Nakajima  
Modeling and Identification I .........................16  
Toru Watanabe, Jerzy T. Sawicki |
Shin Murakami, Takashi Ikeda, Tsubasa Watanabe  
Frequency Noise Rejection for Vibration Minimization in an AMB System  
Inigo Arredondo, Josu Jugo  
Toward Automated AMB Controller Tuning: Progress in Identification and Synthesis  
Jerzy T. Sawicki, Eric H. Maslen |
| 10:50 – 11:10| Development of an Axial Magnetic Bearing for Vertical-Type Centrifugal Separators  
Masahide Ooshima, Hiroshi Kitada  
Adaptive Control for Attenuating Vibrations in AMB Based Systems Using Multirate and Nonuniform Sampling  
Josu Jugo, Inigo Arredondo  
Levitation and Vibration Control of a Flexible Rotor by Using Active Magnetic Bearing  
Naoyuki Tanaka, Toru Watanabe, Kazuto Seto |
| 11:10 – 11:30| Aerodynamic Cross-Coupling in a Flexible Rotor on Magnetic Bearings: Control Design and Implementation  
Simon E. Mushi, Zongli Lin, Paul E. Allaire, Stephen Evans  
Model-Free Control Methods for Recovery from Touchdowns Involving Circular Whirl  
Matthew Owen Thomas Cole  
Passive Magnetic Suspension Limitations for Gravity Compensation  
J.L.G. Janssen, J.J.H. Paulides, E. Lomonova |
| 11:30 – 11:50| Development and Application of Parallel PM Type Hybrid Magnetic Bearings  
Yohji Okada, Kouji Sagawa, Eisaku Suzuki, Ryou Kondo  
Dynamic Performance Limitation in Driving a Radial AMB with Space Vector PWM  
Ahn Hyeong-Joon  
Modeling and Control of an Axial Magnetic Bearing for a Prototype of Electric Motor Supported by Radial Magnetic Bearings  
Santisteban Andres Jose, Plaisant Andre, das Neves Vagner |
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<th>Time</th>
<th>Session</th>
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<td>Dynamic Characteristics of the Magnetic Bearing System with Magnetic Damper</td>
<td>Zhenyu Xie, Longxiang Xu, Hua Gao, Jingting Zhang, Peizhen Huang</td>
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<tr>
<td></td>
<td>Performance Improvement of a Split Winding Bearingless Induction Machine Based on A Neural Network Flux Observer</td>
<td>Jose Alvaro De Paiva, Andres Ortiz Salazar, Andre Laurindo Maitelli, Richard Magdalena Stephan</td>
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<tr>
<td></td>
<td>Study on the Unbalance of Magnetic Suspended Rotor Based on Holospectrum</td>
<td>Yefa Hu, Huachun Wu, Li Wei, Xiaoguang Wang</td>
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<td>12:10 – 13:30</td>
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<td>Johann Wassermann, Satoshi Ueno</td>
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<td>Magnetic Suspensions I &amp; Other Related New Fields .........................18</td>
<td>Uhn Joo Na, Masaya Takasaki</td>
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<td>13:30 – 15:10</td>
<td>Analysis and Control of a Three-Pole Permanent Magnet Type Bearingless Motor</td>
<td>Shyh-Leh Chen, Shang-Yu Hsu</td>
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<td></td>
<td>Numerical and Experimental Simulation of a Vertical High Speed Motorcompressor Rotor Drop onto Catcher Bearings</td>
<td>David Ransom, Andrea Masala, Jeff Moore, Giuseppe Vannini, Massimo Camatti</td>
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<td></td>
<td>Digital Control of Magnetic Levitation for Contactless Delivery Applications</td>
<td>Ki-Chang Lee, Ji-Woo Moon, Yeon-Ho Jeong, Dae-Wook Kang, Dae-Hyun Koo, Uhn-Joo Na, Seung-Heui Lee</td>
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<td>13:30 – 15:10</td>
<td>Sensorless Speed Control of a Permanent Magnet Type Axial Gap Self-Bearing Motor</td>
<td>Dich Quang Nguyen, Satoshi Ueno</td>
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<td>On the Design of an Active Auxiliary Bearing for Rotor/Magnetic Bearing Systems</td>
<td>Iain Stuart Cade</td>
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<td>A Study on Indirect Suspension of Magnetic Target by Actively Controlled Permanent Magnet</td>
<td>Akihiro Yamamoto, Masayuki Kimura, Takashi Hikihara</td>
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<td>Rotor/Auxiliary Bearing Dynamic Contact Modes in Magnetic Bearing Systems</td>
<td>Patrick Sean Keogh, Mehmet Necip Sahinkaya, Clifford Robert Burrows, Iain Stuart Cade</td>
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<td>Study on Shape Control and Vibration Absorber of Strip in Steel Process Line</td>
<td>Atsushi Inoue, Hironori Fujioka, Shigeaki Morii, Mochimitsu Komori</td>
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<td>14:10 – 14:30</td>
<td>Comparison of 2- and 3-Phase Bearingless Slice Motor Concepts</td>
<td>Franz Zurcher, Thomas Nussbaumer, Wolfgang Gruber, Johann Walter Kolar</td>
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<td>Drop Analysis of Auxiliary Bearings in Fluid Film/Magnetic Bearing Supported Rotor</td>
<td>Amir Younan, Tim Dimond, Paul Allaite</td>
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<td>Active Balancing of a Flexible Rotor in Active Magnetic Bearings</td>
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<td>A Novel Controllable Back-up Bearing for Active Magnetic Bearings</td>
<td>Changsheng Zhu</td>
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<td>Electrostatic Suspension by Using Variable Capacitors for Three-Motion Control</td>
<td>Takaaki Kato, Shinya Tsukada, Yuji Ishino, Masaya Takasaki, Takeshi Mizuno</td>
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<td>14:10 – 14:30</td>
<td>Basic Characteristics of Improved Bearingless Motor with Passive Magnetic Bearings</td>
<td>Yukiko Nakano, Tetsuro Asami, Junichi Asama, Akira Chiba, Tadashi Fukao, Takeshi Hoshino, Atsushi Nakajima</td>
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<td>Applications</td>
<td>Ming Chen, Nobuyuki Kurita</td>
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<td>Micro Bearings, Ultra High Speed Bearings &amp; Safety and Reliability Aspects</td>
<td>Matthew Owen Thomas Cole, Tadahiko Shinshi</td>
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<td>15:40 – 16:00</td>
<td>Application of Rotor Unbalance Compensation to AMB-Based Gyroscopic Sensor</td>
<td>Yutaka Maruyama, Takeshi Mizuno, Masaya Takasaki, Yuji Ishino, Hironori Kameno, Atsushi Kubo</td>
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<td>AMB Flywheel-Powered Electric Vehicle</td>
<td>Kenzo Nonami, Budi Rachmanto, Kenta Kuriyama, Yukihiro Sato, Kichihiro Kondo, Atsushi Kubo, Ryoichi Takahata</td>
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<td>Design and Realization of a Miniature Milling Spindle with Active Magnetic Bearings</td>
<td>Maarten Kimman</td>
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<td>16:00 – 16:20</td>
<td>Magnetically Levitated Blood Pump Using LCR Circuits</td>
<td>H. Ming Chen, Thomas J. Walter, Charles J. Prisco, Peter A. Chapman, Arthur C. Donahue</td>
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<td>Flexible Rotor Modeling for a Large Capacity Flywheel Energy Storage System</td>
<td>Seong-Yeol Yoo, CH Park, SK Choi, Myounggyu D. Noh</td>
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<td>A maglev Local Actuator for High Speed Electrical Discharge Machining</td>
<td>Xiaoyou Zhang, Tadahiko Shinshi, Hiroki Morita, Akira Shimokohbe, Tatsushi Sato, Hidetaka Miyake, Takayuki Nakagawa</td>
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<td>Axial Magnetic Bearing Development for the BiVACOR rotary BiVAD/TAH</td>
<td>Nobuyuki Kurita, Daniel Lee Timms, Nick Greatrex, Toru Masuzawa</td>
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<td>Attitude Control of Flywheel with Two-Axis Gimbal and Nonlinear Input Shaping</td>
<td>Budi Rachmanto, Kenzo Nonami, Kenta Kuriyama</td>
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<td>A Sophisticated Active Magnetic Bearing System with Supreme Reliability</td>
<td>Alexander Schulz, Manfred Neumann, Johann Wassermann</td>
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<td>16:40 – 17:00</td>
<td>Application of Active Magnetic Bearing for Tubular Linear Induction Motor in Oil Pumping</td>
<td>Eduardo Alves da Costa, Ivan Eduardo Chabu, Jose Jaime da Cruz</td>
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<td>Cross Feedback Control of Hybrid Magnetic Bearings based on Root Locus</td>
<td>Kai Xiao, Kun Liu, Xiaofei Chen</td>
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<td>A Mini-Centrifugal Blood Pump Using 2-DOF Controlled Magnetic Bearing</td>
<td>Tadahiko Shinshi, Shunji Goto, Xiaoyou Zhang, Akira Shimokohbe, Settsuo Takatani</td>
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<tr>
<td>18:00 –</td>
<td>Traditional Japanese &quot;Noh&quot;</td>
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<td>Aug. 28, 2008 (THU)</td>
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<tr>
<td>8:30 – 9:00</td>
<td>Registration</td>
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<td>9:00 – 10:20</td>
<td>Components &amp; Control I</td>
<td>Eric Maslen, Yohji Okada</td>
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<td>Magnetic Suspensions II &amp; Low Loss Magnetic Bearings</td>
<td>Takeshi Mizuno, Jun Ho Lee</td>
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<td>Passive Suspension</td>
<td>Jan Sandtner, Mochimitsu Komori</td>
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<td>9:00 – 9:20</td>
<td>Effect of Long Cables on AMB Systems</td>
<td>Nicholas Elder, Eric Maslen</td>
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<td>A Controller Design to Suppress the Interference Force of the Propulsion Equipment Acting on the Suspension System in a Magnetically Levitated Train System</td>
<td>Jun Ho Lee</td>
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<td>Application of Diamagnetic Levitation to Mechatronic Systems</td>
<td>François Barrot, Hannes Bleuler</td>
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<td>Time</td>
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<td>10:00 – 10:20</td>
<td>Robust Fuzzy Control of an Active Magnetic Bearing with Delayed Feedback</td>
<td>Kai Zheng, Yanhua Sun, Lie Yu</td>
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<td>10:20 – 10:50</td>
<td>Break</td>
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<td>10:50 – 12:10</td>
<td>Self-Bearing (Beariless) Motors II</td>
<td>Wolfgang Gruber, Akira Chiba</td>
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<td>10:50 – 11:10</td>
<td>Radial Suspension Force Control of Bearless Motor with Flux Equivalent Air-Gap Virtual Winding Current</td>
<td>Huangqiu Zhu, Qiuliang Cheng, Qingshai Wu, Wei Pan</td>
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<td>11:10 – 11:30</td>
<td>Bearingless Segment Motor with Buried Magnets</td>
<td>Wolfgang Gruber, Wolfgang Amrhein, Thomas Stallinger</td>
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<td>11:30 – 11:50</td>
<td>Calculation of Suspending Force for New Bearingless Switched Reluctance Motor</td>
<td>Huijun Wang, Dong-Hee Lee, Jin-Woo Ahn</td>
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<td>11:50 – 12:10</td>
<td>Inverter Voltage and Suspension Characteristics of a Bearless Motor</td>
<td>Miya Amada, Naoya Miyamoto, Takehiro Enomoto, Norimasu Tanabe, Junichi Asama, Akira Chiba, Tadashi Fukao, Satoru Iwasaki, Masatsugu Takemoto</td>
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<td>12:10 – 13:00</td>
<td>Lunch Break</td>
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### Aug. 29, 2008 (FRI)

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>11:00 –</td>
<td>Horyuji Temple Tour</td>
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<td>18:00 –</td>
<td>Banquet</td>
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#### 9:00 – 9:30
- **Registration**

#### 9:30 – 10:30
- **Keynote Address:** The City of Nara: Urban Planning 1,300 Years Ago (Room A)
  - Mr. Tomo Ishimura, Nara National Research Institute for Cultural Properties, Japan

#### 10:30 – 11:00
- **Break**

#### 11:00 – 12:20
- **Control III**
  - Riku Pöllänen, Kenzo Nonami
- **Self-Bearing (Bearingless) Motors III**
  - Domingos David, Yoshi Okada
- **Magnetic Suspensions III**
  - Paulides Johannes, Koichi Oka
- **Trade Offs in LQ/LTR Control Designs for MIMO AMB Systems**
  - Riku Pöllänen
- **5-DOF Controlled Self-Bearing Motor**
  - Tatsuya Ishikawa, Ken-ichi Matsuda, Toru Masuzawa, Ryu Kondo
- **Zero Power Control for Permanent Magnetic Suspension System**
  - Feng Sun, Koichi Oka
- **Robust Control Against Disturbance Model Uncertainty in Active Magnetic Bearings**
  - Sjoerd G. Dietz, Navin Kumar H.M. Balini, Carsten W. Scherer
- **Development of a Lorentz-Force-Type Slotless Self-Bearing Motor**
  - Satoshi Ueno, Shin-ichi Uematsu, Takahisa Kato
- **Experimental Verification of Look-Up Table Based Real-Time Commutation of 6-DOF Planar Actuators**
  - Jeroen De Boeij, Elena Lomonova
- **Observer-Based Unbalance Compensation in LQ-Control of AMBs**
  - Riku Pöllänen
- **LQR Control of a Bearingless Machine Implemented with a DSP**
  - Wilmar Kauss, Afonso Gomes, Richard Stephan, Domingos David
- **Experimental Study on the Basic Characteristic of Flux Path Control Magnetic Suspension**
  - Munehiro Furutachi, Shunsuke Inaba, Masaya Takasaki, Yuji Ishino, Takeshi Mizuno
- **A Novel Controller with Force Feedback of Active Magnetic Bearings**
  - Xiaofei Chen, Kun Liu, Kai Xiao
- **Independent Control of Torque and Radial Force in Bearingless Switched Reluctance Motor**
  - Xin Cao, Zhiqian Deng, Gang Yang, Xiaolin Wang
- **Geometrical Design for a Large Magnetic Supporting System Considering Coupling Effect**
  - Jie Tian, Yong Wang, Han Zhao, Bing Zhang, Wenting Huang, Wenting Huang

#### 12:00 – 13:20
- **A Novel Passivity Based Control without Conventional Cross Feedback**
  - Satoru Sakai, Kenta Kuriyama, Kenzo Nonami
- **A Supercritical 250 kW Industrial Air Compressor Prototype**
  - Erkki Lantto, Ville Tommila
- **Sensors, Actuators, Controllers II & Self-Sensing (Sensorless) Techniques I**
  - Zhu Changsheng, Hideki Kanehako
- **Contact-Free Bearings For Flywheels II**
  - Jose Martin Echeverria, Satoru Sakai
- **Industrialization II**
  - Erkki Lantto, Eiji Tsunoda
- **Zhu Changsheng, Hideki Kanehako**
- **A Novel Passivity Based Control without Conventional Cross Feedback**
  - Satoru Sakai, Kenta Kuriyama, Kenzo Nonami
- **A Supercritical 250 kW Industrial Air Compressor Prototype**
  - Erkki Lantto, Ville Tommila
- **Active Axial Electromagnetic Damper**
  - Alexei Filatov, Larry Hawkins, Venky Krishnan, Bryan Lam
<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
<th>Session</th>
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<tbody>
<tr>
<td>13:40 – 14:00</td>
<td>An Approach to a 3-pole Active Magnetic Bearing System Fed by a Matrix Converter</td>
<td>Javier Vadillo, Jose Martin Echeverria, Ibón Elosegui, Luis Fontan</td>
<td>Automatic Thermal Expansion Compensation of the AMB Used in Precision Grinding Machine</td>
</tr>
<tr>
<td>14:00 – 14:20</td>
<td>Attitude Stabilization Control of AMB-Flywheel Supported by Two-Axes Gimbals</td>
<td>Kenta Kuriyama, Kenzo Nonami, Budi Rachmanto</td>
<td>Design and Manufacturing of a 70 kW, 36000 rpm Milling Spindle</td>
</tr>
<tr>
<td>14:20 – 14:40</td>
<td>Preliminary Tests for the HTR-10 Helium Circulator with the Active Magnetic Bearings</td>
<td>Diao Xingzhong, Shuyuan Yu</td>
<td>Self-Sensing of Nonlaminated Axial Magnetic Bearings : Modelling and Validation</td>
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<tr>
<td>14:40 – 15:10</td>
<td>Break</td>
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<td>16:10 – 16:30</td>
<td>Design and Realization of Magnetic Suspended Device Based on Edge Effect</td>
<td>Huachun Wu, Xiaoguang Wang, Li Wei, Yefa Hu</td>
<td>Analysis of a Dynamical Electromechanical Model</td>
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<tr>
<td>16:30 – 17:00</td>
<td>Design and Realization of Magnetic Suspended Device Based on Edge Effect</td>
<td>Huachun Wu, Xiaoguang Wang, Li Wei, Yefa Hu</td>
<td>Analysis of a Dynamical Electromechanical Model</td>
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<td>17:00 –</td>
<td>Farewell Party</td>
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Keynote Addresses

Keynote Address 1
9:00 – 10:00 (After Welcome Address), Aug. 28, 2008, at Room A
“20 Years ISMB: Then, Now, Future”
Prof. Hannes Bleuler, EPFL, Switzerland
Chair: Takeshi Mizuno (Saitama University)

Keynote Address 2
9:30 – 10:30, Aug. 28, 2008, at Room A
“The City of Nara: Urban Planning 1,300 Years Ago”
Mr. Tomo Ishimura, Nara National Research Institute for Cultural Properties, Japan
Chair: Kenzo Nonami (Chiba University)

Abstract: The city of Nara was one of the earliest capitals in ancient Japan and positioned at the eastern terminal of the Silk Road, and it is inscribed on the list of World Heritage. Whereas some ancient temples such as Todaiji and Kofukuji remain in existence, the Royal Palace of Nara and most of the urban area at that time turned into field after its abandonment. Nara National Research Institute for Cultural Properties has carried out archaeological excavations for about fifty years as a national project, and obtained substantial knowledge about the capital 1,300 years ago. In this talk I present some studies on the ancient city of Nara and its implication for understanding the significance of founding this planned city in the international political situation in East Asia around the 8th century.
**Magnetic Actuators I**

10:30 – 12:10, Aug. 27, 2008 (WED), Room A

*Co-Chairs: Masahide Ooshima (Tokyo University of Science, Suwa College) Shyh-Leh Chen (National Chung-Cheng University)*

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**NUMERICAL SIMULATIONS AND EXPERIMENTS ON VIBRATION AT MAJOR CRITICAL SPEED OF ROTOR SUSPENDED BY MAGNETIC BEARING (INFLUENCE OF DECREMENT OF MAGNETIC FORCE DUE TO EDDY CURRENT CAUSED BY ROTATION)**

S. Murakami1, T. Ikeda2 and T. Watanabe2

1Shimane University, 2Daido Castings Co. Ltd.

- Precise prediction of vibration characteristics of a rotor suspended by magnetic bearing
- The equation of motion is derived with nonlinearity of magnetic force
- Influence of decrement of magnetic force due to eddy current caused by rotation is investigated
- The experimental results have good agreements with the simulation by proposed method

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**Proposal of an axial magnetic bearing for centrifugal separators**

- Structure
- Control system
- Analyses of magnetic force by Finite Element Method
- Design of electromagnet and PM sizes
- Axial magnetic forces at starting and high speed operation
- Analyses in parallel and conical modes of rotor motion

---

**Development of an Axial Magnetic Bearing for Vertical-type Centrifugal Separators**

M. Ooshima1, H. Kitada2

1Tokyo Univ. of Science, Suwa College, 2CMS Co., Ltd.

- Proposal of an axial magnetic bearing for centrifugal separators
  - Structure
  - Control system
- Analyses of magnetic force by Finite Element Method
  - Design of electromagnet and PM sizes
  - Axial magnetic forces at starting and high speed operation
  - Analyses in parallel and conical modes of rotor motion

---

**Aerodynamic Cross-coupling in a Flexible Rotor: Control Design and Implementation**

Simon Mushi1, Zongli Lin1, Stephen Evans2 and Paul E. Allaire2

1Department of Electrical and Computer Engineering
2Department of Mechanical and Aerospace Engineering
University of Virginia

- Design of rotor-AMB system to emulate small industrial compressor
- Aerodynamic cross-coupled stiffness introduced by using an active magnetic bearing
- Synthesis of robust controllers to stabilize over a wide range of destabilizing cross-coupled stiffness.
- Real-time controller implementation currently underway

---

**Development and Application of Parallel PM Type Hybrid Magnetic Bearings**

Yohji Okada*, Kouji Sagawa*, Eisaku Suzuki*, and Ryou Kondo*

*Dept. of Mechanical Eng., Ibaraki University

- Type 1 ABB is shown in the left, while type 2 is shown in the middle figures. They have strong force factor with wide airgap of 4mm.
- The levitation is stable and low power consumption is recorded.
- The unbalance responses are low level as shown in the right figure (Type 2 is shown).

---

**DYNAMIC CHARACTERISTICS OF THE MAGNETIC BEARING SYSTEM WITH THE MAGNETIC DAMPER**

Xie Zhenyu, Xu Longxiang, et al,
College of Mechanical and Electrical Eng., Nanjing Univ. of Aeronautics and Astronautics, Nanjing, 210016 China

- Dynamic characteristics of the magnetic bearing system with the magnetic damper are investigated.
- Compared with the ordinary magnetic bearing system, the modal damps on the 1st and 2nd bending critical speeds have increased a lot, and the system can get across the first two bending critical speeds safely.
Sensors, Actuators, Controllers I
10:30 – 12:10, Aug. 27, 2008 (WED), Room B
Co-Chairs: Josu Jugo (University of the Basque Country), Atsushi Nakajima (JAXA)

10:30 – 10:50
Frequency error rejection for vibration minimization in an AMB System

I. Arredondo and J. Jugo
Dept. of Electricity&Electronics, Fac. Science&Tech. UPV/EHU

When a vibration suppression adaptive algorithm is implemented to enhance an AMB based system, a good frequency measurement or estimation of the synchronous rotation is essential.

In this paper, two frequency disturbance rejection methods applied to the frequency sensor measurement are compared. The first method is based on the use of a Kalman Filter (KF) while the second, is the implementation of a Frequency Locked Loop (FLL). Both have advantages and disadvantages related to the available hardware, noise type of the sensor, the fact of vibration minimization and the computational cost of the adaptive algorithm.

Finally, experimental proofs in a laboratory testbed, based on the MB2500 Rotor Dynamics, show the effectiveness of each method.

10:50 – 11:10
Adaptive Control for Attenuating Vibrations in AMB based systems using Multirate and Nonuniform Sampling

J. Jugo and I. Arredondo
Dept. Electricity and Electronics, Leioa (UPV/EHU)

• A feedforward adaptive vibration controller using multirate and nonuniform sampling methods is presented
• Reducing the mean sampling rate and advantages in the minimization of execution time of the algorithms
• Experimental results validate the theoretical reduction of vibrations
• The testbed is based on a MB2500 rotor dynamics controlled by a real-time system implemented by means of LabVIEW and using a FPGA

11:10 – 11:30
Model-Free Control Methods for Recovery from Touchdowns Involving Circular Whirl

Matthew O. T. Cole
Dept. of Mechanical Eng., Chiang Mai University, Chiangmai, Thailand

• Dynamics associated with rotor-state touchdowns involving full circular rub are considered
• Expected range of phase shifts in signals are examined with the aim of developing model-free control algorithms that can recover contact-free levitation from a state involving persistent rub with touchdown bearings
• Requirements for successful operation, in terms of available sub-models and measurement information, as well as possible deficiencies are explained and verified through experimental tests on a multi-mode flexible rotor test rig.

11:30 – 11:50
DYNAMIC PERFORMANCE LIMITATION IN DRIVING A RADIAL AMB WITH SV PWM

H.J. Ahn
Dept. of Mechanical Eng., Soongsil University, Korea

• Driving a radial AMB using SV PWM – Like a two phase motor
• Two driving configurations: full performance & economy
  – Reduced voltage region Dynamic performance
• Two coil connection architectures: two opposing EMs & two adjacent EMs
• Mathematical analysis & Simulation
  – Proper coil connection minimizes the dynamic performance degradation

11:50 – 12:10
Performance Improvement of a Split Winding Bearingless Induction Machine Based on a Neural Network Flux Observer

José A. Paiva1, Andrés O. Salazar1, André L. Matteli1 and Richard M. Stephan3
Federal Center of Tec. Eduction of R.G. do Norte1, Federal University of R. G. do Norte2, Federal University of Rio de Janeiro2

• This work describes the performance improvement of a 4 poles 1.1 kW split winding bearingless induction machine based on a neural rotor flux observer
• The system control is implemented in a DSP and executes asynchronously the vector speed control, the radial positioning control and the stator winding current control
• The neural flux observer compensates for parameter variations due to temperature changes or due to the rotor magnetic saturation
• Comparisons with a fixed parameter observer validate the proposed method.
Modeling and Identification I
10:30 – 12:10, Aug. 27, 2008 (WED), Room C
Co-Chairs: Toru Watanabe (Nihon University), Jerzy T. Sawicki (Cleveland State University)

10:30 – 10:50
**Toward Automated AMB Controller Tuning: Progress in Identification and Synthesis**
Jerzy T. Sawicki1 and Eric H. Maxem1
1Cleveland State University, 2University of Virginia

**Research Objective**
- Examine the general characteristics of the plant that govern the requirements of an automated tuning process
- Develop a computational scheme for ascertaining whether a given model and associated uncertainty description (the components of mu-synthesis) properly covers measured dynamics of the plant

**Conclusions**
- Experimental data analysis show the need for model validation
- Developed outline for the robust control model validation

10:50 – 11:10
**Levitation and Vibration Control of a Flexible Rotor by using Active Magnetic Bearing**
N. Tanaka1, T. Watanabe1 and K. Seto2
1Dept. of Mechanical Eng., Nihon University, 2Seto Vibration Control Lab.

- This Paper Presents a New Modeling Method and a Control System Design Procedure for a Flexible Rotor
- New Modeling Method Named as “Extended Reduced Order Physical Model”
- New Control System Named as “Filtered LQ Control Combined with PID”
- The Purpose of Our Research is to Rotate the Rotor for Passing Through 2nd Critical Speeds

11:10 – 11:30
**PASSIVE MAGNETIC SUSPENSION LIMITATIONS FOR GRAVITY COMPENSATION**
J.L.G. Janssen, J.J.H. Paullides and E. Lomonova
Dept. Elect. Eng., Eindhoven University of Technology, the Netherlands

- The minutest vibrations have disastrous effects on the performance of the static and moving parts of high-precision machines
- Fast-solving analytical models for a passive/active electromagnetic solution are presented in this paper
- Several topologies are discussed which illustrate the feasibility of using passive permanent magnets for gravity compensation in this demanding high precision industrial application

11:30 – 11:50
**Modeling And Control of an Axial Magnetic Bearing for a Prototype of Electric Motor Supported by Radial Magnetic Bearings**
V. das Neves1, J. A. Santisteban1 and A. Plaisant2
1Brazilian Navy, 2Electric Eng. Dept., PGMEC, Fluminense Federal University, Brazil

- An improved modeling for the axial behavior of a rotor supported by radial magnetic bearings, having in mind the application of axial magnetic bearings, was realized
- A second-order approximate model was derived from an experimental test. It was confirmed that the equivalent stiffness and damping depend on the bias currents of the pre-existent radial magnetic bearings
- A simple analog circuit was designed and tested to control the axial displacement of the rotor. Successful experimental results confirm the validity of this approach

11:50 – 12:10
**Study on the Unbalance of Magnetic Suspended Rotor Based on Holospectrum**
Yefa HU1, Huachun WU1, Li WEI1 and Xiaoguang WAND1
1School of Mechanical Engineering, Wuhan Univ. of Technology

- Principle of Holospectrum
- Compensation principle of MSB Unbalance based on Holospectrum
- Compensation method for MSB imbalance
- Experiment research

**Room C**

- Upper floor
- Ground floor
- Room B
- Room A
- Entrance

Upper floor:
- S
- Room C

Ground floor:
- Room B
- T
- T
- T
- Room A
- Entrance
Analysis and Control of a Three-Pole Permanent Magnet Type Bearingless Motor
Shyh-Leh Chen and Shang-Yu Hsu
Department of Mechanical Engineering.

- The Eleventh International Symposium on Magnetic Bearings.
- From August 26 to 29, 2008.
- Held at Nara Prefectural New Public Hall in Nara.

Sensorless speed control of a permanent magnet type axial gap self-bearing motor (AGBM).
Dich Quang, Nguyen¹ and Satoshi Ueno¹
¹Dept. of Mechanical Eng., Ritsumeikan University, Japan
This paper presents an analytical and experiment evaluation of sensorless speed vector control of AGBM, which includes:
I. Introduction
II. Sensorless closed loop vector control
A. Vector control scheme of AGBM
B. Mathematical model of AGBM
C. Luenberger observer
III. Implementation and results
A. Control hardware
B. Experimental results
IV. Conclusion

Basic Characteristics of Improved Bearingless Motor with Passive Magnetic Bearings
Y. Nakano¹, T. Asami¹, J. Asama¹, A. Chiba¹, T. Fukao¹, T. Hoshino² and A. Nakajima²
¹Tokyo University of Science, ²Japan Aerospace Exploration Agency
- Basic characteristics of an improved bearingless motor with passive magnetic bearings (PMBs) are presented.
- The experimental and calculated results of the proposed machine with PMBs are compared to results without PMBs.
- It is presented that an improved bearingless motor with PMBs has significantly enhanced the axial and conical stiffness.

COMPARISON OF 2- AND 3-PHASE BEARINGLESS SLICE MOTOR CONCEPTS
Franz Zürcher*, Thomas Nussbaumer*, Wolfgang Graber**, Johann W. Kolar***
*ETH Zürich, **Levitronix GmbH, ***ACCM GmbH (J. K. University Linz)
- Contactless levitation and rotation through a hermetically closed process chamber
- Application in processes for chemical, pharmaceutical, biotechnology and semiconductor industry
- Utilization of “bearingless slice motor” concept
- Comparison of 2-phase and 3-phase setups
- Derivation of acceleration performance parameters
- Experimental verification

Electromechanical Interaction in Eccentric-rotor Cage Induction Machine Equipped with a Self-bearing Force Actuator
A. Laiho¹, K. Tammi², J. Orivuori², A. Sinervo³, K. Zenger², A. Arkkio³
¹VTT Technical Research Centre of Finland, ²Helsinki University of Technology, Control Engineering Laboratory
³Helsinki University of Technology, Laboratory of Electromechanics
- Built-in force actuator
- Low-order parametric actuator-rotor model
- Flexural rotor vibration control
- Experiments by a small two-pole motor
- 85% reduction in vibration amplitude
Numerical and Experimental Simulation of a Vertical High Speed Motorcompressor Rotor Drop Onto Catcher Bearings

D. Ransom, A. Masala, J. Moore, G. Vannini, M. Camatti
South West Research Institute, GE Oil&Gas

A joint research program between GE Oil&Gas and SwRI was carried out to predict and test the dynamics of a vertical rotor drop on catcher bearings:
- The numerical code developed integrates the rotor and casing dynamics through CMS reduced model with non linear behavior of catcher bearings and damping system.
- The test rig was designed based on rotordynamic similitude to GE Blue-C® subsea motor-compressor. Main features:
  - Single-shaft/vertical rotor on three AMBs
  - 1:3 geometric scale factor to Blue-C® machine
  - Drop speed up to 30000 rpm
- A comparison between experimental and numerical results is presented.

On the Design of an Active Auxiliary Bearing for Rotor/Magnetic Bearing Systems

I.S. Cade, M.N. Sahinkaya, C.R. Burrows and P.S. Keogh
Department of Mechanical Engineering, University of Bath, Bath, BA2 7AY, UK

- Active auxiliary bearing design objectives include:
  - Reducing the rotor/bearing contact forces
  - Influencing the rotor dynamics to prevent, or retrieve, a trapped contact mode.
- A piezo actuated system, using a closed hydraulic coupling, is presented.
- The dynamic performance of the actuators and hydraulic line are identified.
- Closed loop control of the active auxiliary bearing.

Rotor/Auxiliary Bearing Dynamic Contact Modes in Magnetic Bearing Systems

P.S. Keogh, M.N. Sahinkaya, C.R. Burrows and I.S. Cade
Dept. of Mechanical Eng., University of Bath, Bath BA2 7AY, UK

- Active auxiliary bearing design proposed
- Incorporation of piezoelectric actuators
- Closed or open-loop bearing control
- Without control, rotor may become trapped in contact modes
- Actuation of the auxiliary bearing is simulated to show restoration of contact-free levitation
- Future experimental tests proposed

TRANSIENT DROP ANALYSIS OF AUXILIARY BEARINGS IN FLUID FILM/MAGNETIC BEARING SUPPORTED ROTOR

Amir Younan, Tim Dimond and Paul Allaire
Mechanical and Aerospace Engineering Department, University of Virginia

- Design of auxiliary bearings for a new fluid film bearing test rig.
- Unique design due to the partial support offered by the central tested journal bearing.
- A three mass model is selected to conduct the transient analysis of the rotor drop.
- Hertzian contact theory is used to describe the contact between the rotor and the inner race of the auxiliary bearings.
- The analysis includes different sets of auxiliary bearings.

A Novel Controllable Back-up Bearing for Active Magnetic Bearings

Zhu Changsheng
College of Electrical Engineering, Zhejiang University, China

- A back-up bearing is one of key elements to use successfully the AMBs in the rotational machinery.
- This paper presents a novel controllable back-up bearing which is based on eddy-current principle and fixed clearance ball bearing.
- The objective of this paper is to investigate experimentally the dynamic behavior of the back-up bearing, and to determine the effective of the back-up bearing in controlling the transient vibration during rotor dropping.
Digital Control of Magnetic Levitation for Contactless Delivery Applications

1Korea Electrotechnology Research Inst., 2Kyungnam University

- EMS (Electromagnetic Suspension) can be a best bearing because of its contactless property
  - No Friction, Particle generation,
  - Vibration free, Clean
- Decoupled control (3-DOF)
  - PID control for each DOF is implemented and tested for a EMS simulator.
  - Stable and good performance

A Study on Indirect Suspension of Magnetic Target by Actively Controlled Permanent Magnet

A. Yamamoto, M. Kimura, T. Hikihara
Dept. of Electrical Eng., Kyoto University

- Indirect suspension system: an electromagnet (EM), a permanent magnet (PM) and a target.
- Control method: proportional-derivative (PD) controller with respect to the position and the velocity of the PM.
- Dynamics of levitated bodies
  - restricted in one dimension.
  - depicted by a magnetic charge model.
- Behaviors of levitated bodies near the reference positions
  - studied numerically and experimentally.
  - able to be described by the depicted model.

Study on Shape Control and Vibration Absorber of Strip in Steel Process Line

A. Inoue1, H. Fujikawa2, S. Mori2 and M. Komori2
1Mitsubishi Heavy Industries, Ltd., 2Mitsubishi-Hitachi Metals Machinery, Inc.

- In a steel process line, the shape controller and vibration absorber of steel strip are important devices for improving strip quality and line speed up.
- We report on the application of an electromagnetic method of absorbing vibrations and correcting the deformation of strips.
- This device was able to be used with stability in the steel process line, the vibration decrease and shape were corrected

Active Balancing of a Flexible Rotor in Active Magnetic Bearings

Francis Fomi and Rainer Nordmann
Mechatronik im Maschinenbau, Technische Universitaet Darmstadt 64287 Germany

A complete automatic balancing strategy is here proposed, which allows to realize an uninterrupted control of the balancing states during operation. It is based on the combination of the active magnetic bearings, the active balancing devices, and the drive motor and is applied to a flexible low pressure shaft of a helicopter engine test rig. Experimental results validate the efficiency of the proposed strategy.

ELECTROSTATIC SUSPENSION IN 3-DOF BY USING A VARIABLE CAPACITOR

Graduate School of Science and Eng., Saitama University

- Voltage control system using variable capacitors is applied to electrostatic suspension.
- The voltage applied to an electrostatic actuator can be adjusted by changing a capacitance of the variable capacitor.
- Non-contact electrostatic suspension can be achieved.
Application of Rotor Unbalance Compensation to AMB-Based Gyroscopic Sensor

Y. Maruyama1, T. Mizuno1, M. Takasaki1, Y. Ishino2, H. Kameno3, and A. Kubo3
1Graduate School of Science & Eng., Saitama Univ., 2Innovative Research Org., Saitama Univ., 3Research & Development Center, JTEKT.

- AMB-based gyro measures angular velocity using control current of the AMB.
- The measurement has undesirable components due to rotor unbalance.
- Unbalance compensation is applied to the AMB-based gyro in order to reduce the components.
- The components decreased by 80% due to the compensation.

A Magnetically Levitated Blood Pump using LCR Circuits

H. M. Chen1, Peter A. Chapman1, Arthur C. Donahue1, Charles J. Prisco1, and Thomas J. Walter1
1Foster-Miller, Inc.

- Implantable blood pump designed for use as a left ventricular assist device
- LCR circuit is self-sensing, self-positioning maglev technique
- Electromagnet (L) connected in series with a capacitor (C) and a resistor (R)
- Two titanium pump prototypes built and tested with demonstrated performance of 5 l/min and 100 mm-Hg and stable operation of the LCR circuit bearings

Axial Magnetic Bearing Development for the BiVACOR rotary BiVAD/TAH

Nobuyuki Kurita Miyakonojo National College of Technology
Daniel L Timms The prince Charles Hospital
Nicholas Greatrex Queensland University of Technology
Toru Maszawa Ibaraki University

- A third generation rotary BiVAD/TAH is suggested to treat end stage bi-ventricular heart failure.
- To develop the rotary BiVAD, a magnetic levitated motor bearing is designed and fabricated.
- To confirm the performance of fabricated test rig, static and dynamic characteristics are measured.
- The results were discussed to produce a miniature implantable device suitable for chronic animal implantation.

Application of Active Magnetic Bearing for Tubular Linear Induction Motor in Oil Pumping

E. Costa, I. Chabu, and J. Cruz
Dept. of Electric Eng., University of São Paulo

- 8-pole AMB and DC-Excited primitive bearingless machine.
- System configuration: AMB, sensor, controller and power amplifier.
- AMB actuator project.
- Finite element analysis: magnetic flux density and radial force and current relationship.
- Mathematical model.
- Controller.
- Simulation results.
FLEXIBLE ROTOR MODELING FOR A LARGE CAPACITY FLYWHEEL ENERGY STORAGE SYSTEM

Seong-yeol Yoo1, Cheol-hoon Park2, Sang-kyu Choi2, Myounggyu Noh1
1Dept. of Mechatronics Eng., Chungnam National University Daejeon Korea
2Mechatronics Application Team Korea Institute of Machinery and Materials

ABSTRACT

When we design a controller for the active magnetic bearings that support a large rotor, it is important to have an accurate model of the rotor. For the case of the flywheel that is used to store energy, an accurate rotor model is especially important because the dynamics change with respect to the running speed due to gyroscopic effects. In this paper, we present a procedure of deriving an accurate rotor model of a large flywheel energy storage system using the element method. The system is designed to store 5kWh at maximum speed of 18,000 rpm. The model can predict the first and the second bending mode which match well with the experimental results obtained from a prototype flywheel energy storage system.
Micro Bearings, Ultra High Speed Bearings & Safety and Reliability Aspects
15:40 – 17:00, Aug. 27, 2008 (WED), Room C
Co-Chairs: Matthew Owen Thomas Cole (Chiang Mai University), Tadahiko Shinshi (Tokyo Institute of Technology)

15:40 – 16:00

DESIGN AND REALIZATION OF A MINIATURE MILLING SPINDLE WITH ACTIVE MAGNETIC BEARINGS
M.H. Kimman, A. Borisavljevic, H.H. Langen, H. Polinder, R. Munnig Schmidt
Mechatronic System Design, Delft University Of Technology

- Micro Milling with Miniature AMB Spindle
- Aiming at 300 000 rpm and 0.1 μm positioning uncertainty
- First Prototype built
- Prototype is running at 120 000 rpm
- Second Prototype under design
- Novel combined bearing setup supporting very compact disk shaped rotor

16:00 – 16:20

A Maglev Local Actuator for High Speed Electrical Discharge Machining
X. Zhang1, T. Shinshi1, H. Morita1, A. Shimokohbe1, T. Sato2, H. Miyaki2 and T. Nakagawa2
1Precision and Intelligence Laboratory, Tokyo Institute of Technology, 2Advanced Technology R&D center, Mitsubishi Electric Corporation

- A compact 5-DOF controlled maglev local actuator (MLA) is proposed to improve machining speed and accuracy in electrical discharge machining. The MLA has a novel magnetic coupling mechanism to supply a discharge current from the MLA stator to the magnetically levitated spindle without the direct contact with brushes.
- The MLA has a few μm and several ten μrad positioning resolution, bandwidths greater than 100Hz in the 5-DOF, and a stroke of 2mm in the thrust direction.

16:20 – 16:40

A Sophisticated Active Magnetic Bearing System with Supreme Reliability
A. Schulz, B. Gross, M. Neumann, J. Wassermann
Institute of Mechanics and Mechatronics, Vienna University of Technology

- Provides bearing capacity even in case of a defect within any sub-assembly over the whole operating time.
- Completely decoupled electromagnet-channels configured in hot redundancy.
- Details on ...
  - Functionality,
  - Error detection,
  - Safe decoupling,
  - Hot-swap controller amplifier modules.

16:40 – 17:00

A MINI-CENTRIFUGAL BLOOD PUMP USING A 2-DOF CONTROLLED MAGNETIC BEARING
T. Shinshi1, S. Goto1, X. Zhang1, A. Shimokohbe1 and S. Takatani2
1Tokyo Institute of Technology, 2Tokyo Med. and Dent. University

- A mini-centrifugal blood pump (CBP) using maglev technology was developed as a ventricular assist device.
- The impeller was supported by a compact two- degrees-of-freedom controlled magnetic bearing and was rotated by a built-in brushless motor.
- CBP dimensions: 55mm in diameter, 25mm in height, 99 ml in total volume and 16 ml in priming volume.
- The pump achieved a flow of 5 L/min at 100mmHg at a rotational speed of 2,200rpm.
Effect of Long Cables on AMB Systems
N. Elder¹ and E. Maslen²
¹TRAX LLC., ²University of Virginia

- Modeled dynamics of long cable sets
- Examined model performance experimentally
- Looked at potential effects on power amplifier stability
- Suggested solution
- Looked at effects on coil drive / sensor noise coupling
- Suggested low noise transmission scheme

Decoupled Control Using Redundant Coordinates for Three-pole Hybrid Active Magnetic Bearing System
S. H. Park¹ and C.-W. Lee²
¹Dept. of Mechanical Eng., KAIST, Korea

- Decoupled identical PD control scheme is proposed for 3-pole AMB
- Using redundant coordinates \((\theta_0, \theta_1, \theta_2)\)
- 3 Hall sensors are used to detect the rotor position instead of extra proximity probes
- Ring-type permanent magnet bearing is used stabilizing axial and tilting motion
- Experimental results show stable levitation and rotation up to 5,000 rpm

Robust Fuzzy Control of a Nonlinear Magnetic Bearing System with Computing Time Delay
Kai Zheng, Yanhua Sun, and Lie Yu
Institute of Mechatronics and Information Systems, Xi’an Jiaotong University
Xi’an, China

- This paper presented a robust fuzzy logic-base control scheme for a nonlinear magnetic bearing system with delayed feedback. A proper Takagi-Sugeno fuzzy model was chosen to represent the nonlinear magnetic bearing. A fuzzy-model-based PDC controller was designed in terms of a proposed delay-dependent stability criterion which guarantees the asymptotic stability of the fuzzy model. The results of simulation verified the effectiveness and superiority of the proposed method.

The magnetic bearing
Experimental study on the Adjustability of Radial Stiffness in a Repulsive Magnetic Bearing Device

Max Eirich, Yuji Ishino, Masaya Takasaki and Takeshi Mizuno
Graduate School of Science and Engineering, Department of Mechanical Engineering, Saitama University, Shimo – Okubo 255, 338-8570 Saitama, Japan
meirich@mech.saitama-u.ac.jp

- Permanent Magnetic Bearing
- Independent Motion Control
- Changing of Radial Stiffness

A Controller Design to Suppress the Interference Force of the Propulsion Equipment Acting on the Suspension System in a Magnetically Levitated Train System

Jun-Ho Lee
Korea Railroad Research Institute

- Fundamental mathematical model of the Maglev system.
- Suppression of the interference force of the propulsion equipment.
- Sliding mode controller with integrator.
- Curve fitting for the normal force of the propulsion system.
- Dynamic simulations using Matlab/Simulink

Passive Attraction Reduction for Linear Permanent Magnet Actuators

J.J.H. Paulides, J.L.G. Janssen and E. Lomonova
Dept. Electr. Eng., Eindhoven University of Technology, the Netherlands

- In pick and place machines, attraction force becomes a problem due to reduced bearing lifetime
- This paper researches an attraction force compensator to reduce stress on the bearings
- 2D and 3D models are used, analytical and in FEM
- For cost considerations, the minimum mass magnet topology is found

Configuration Design and 3D-FEM Analysis for a Radial-Axial Hybrid Magnetic Bearing

Qinghai Wu, Huangqiu Zhu, Dehong Zhu
School of Electrical and Information Engineering, Jiangsu University, China

- Introduction
- Configuration and Operating Principle of the Radial-Axial HMB
- Mathematics Models and the Control Scheme of the Radial-Axial HMB
- Prototype Parameters
- 3D-FEM Analysis of the Radial-Axial HMB
- Conclusions
Passive Suspension
9:00 – 10:20, Aug. 28, 2008 (THU), Room C
Co-Chairs: Jan Sandtner (EPFL), Mochimitsu Komori (Kyushu Institute of Technology)

9:00 – 9:20
Application of Diamagnetic Levitation in Mechatronic Systems
F. Barrot¹,² and H. Bleuler³
¹LSRO, Ecole Polytechnique Fédérale de Lausanne, ²EMPA Dubendorf

- Diamagnetic levitation: the only passive and stable levitation at room temperature.
- Very scarcely used in engineering.
- Can be used to design mechatronic systems exempt of friction and mechanical contact, leading to high precision sensors and actuators.
- Offers great potentials for small size mechatronic systems.

9:20 – 9:40
Design of Novel Contact-free Disk Suspension and Rotation System utilizing Diamagnetic Graphite
Haruhiko Suzuki, Kazuho Itatsu, Ryosuke Saito, Minoru Kanke, Atsushi Ito
Dept. of Electrical Eng., Fukushima Nat'l College of Tech., Iwaki, Fukushima 970-8034, Japan

- Topics:
  - Passive magnetic levitation of diamagnetic graphite at room temperature
  - Extremely energy-saving acceleration motion
  - Experimental result of successive acceleration motion
  - Concept & design of continuous rotation motion

9:40 – 10:00
Energy Storage Flywheel System With SMB And PMB And It's Performances
Hidashi Misuda, Mudhual Sibdaik, Daichi Hirasuka and Mochimitsu Komori
Graduated School of Engineering, Kyushu Institute of Technology

- The flywheels for electrical storage using superconductor have the advantages of long life, high energy density, and high efficiency.
- Our experimental machine uses the superconducting magnetic bearing (SMB) together with the permanent magnetic bearing (PMB).
- The improvement of the system was to suggest a new structure of PMB, an improvement of the generating motor, and a system for measuring and evaluating momentary voltage drop.

10:00 – 10:20
Compact Passive Electrodynamic Thrust Bearing
Jan Sandtner ¹,², Hannes Bleuler ²
¹ Silphenix GmbH, Oberdorf, ² IMT, EPFL Lausanne, both Switzerland

- New type of passive thrust bearing
- Zero losses in nominal position
- Cylindrical bundle of thincopper wires on stator, short circuited at end faces
- PM array with back iron on (outer) rotor
- Well suited for flywheels
Self-Bearing (Bearingless) Motors II
10:50 – 12:10, Aug. 28, 2008 (THU), Room A

Co-Chairs: Wolfgang Gruber (Johannes Kepler University Linz),
Akira Chiba (Tokyo University of Science)

10:50 – 11:10

RADIAL FORCE CONTROL OF BEARINGLESS MOTOR WITH FLUX EQUIVALENT AIR-GAP VIRTUAL WINDING CURRENT

Huangqiu Zhu, Quiliang Cheng, Qinghai Wu, Wei Pan
School of Electrical and Information Engineering, Jiangsu University

- Introduction
- Analysis method with flux equivalent air-gap virtual winding current
- Radial suspension force control of bearingless motor with flux equivalent air-gap virtual winding current
- Analysis of experiment results
- Conclusions

11:10 – 11:30

Bearingless Segment Motor with Buried Magnets

W. Gruber, W. Amrhein, T. Stallinger
Institute of Electrical Drives and Power Electronics
Johannes Kepler University Linz (Austria)

- Bearingless segment motor.
- Rotor features buried magnets similar to common synchronous machines.
- 5 stator segments with concentrated windings generate motor torque and bearing forces simultaneously.
- Appropriate nonlinear control scheme.
- Hall-sensor considerations.
- Finite element optimization
- Prototype measurements.

11:30 – 11:50

Calculation of suspending force for new Bearingless Switched Reluctance Motor

Huijun Wang, Dong-Hee Lee, Jin-Woo Ahn
Kyungsung University, Korea

- Proposed novel structure of bearingless switched reluctance motor (BLSRM).
- Comparison between proposed structure and conventional one.
- Permeance analysis of proposed BLSRM.
- Design of proposed BLSRM.
- Simulation of control method for BLSRM.

11:50 – 12:10

Inverter Voltage and Suspension Characteristics of a Bearingless Motor

M. Amada¹, N. Miyamoto¹, T. Enomoto¹, N. Tanabe¹, J. Asama¹, A. Chiba¹
T. Fukao¹, S. Iwasaki² and M. Takemoto²
¹Tokyo University of Science, ²Musashi Institute of Technology, ³Hokkaido University

- Two types of voltage sources inverters (single phase 100V and three-phase 200V) are adapted in a bearingless motor.
- The magnetic suspension characteristics and the start-up processes are compared with those inverters experimentally.
- It is found that the noises and the vibration amplitudes with the 100V inverter are less than those with the 200V inverter.
Industrialization I
10:50 – 12:10, Aug. 28, 2008 (THU), Room B
Co-Chairs: Larry Hawkins (Calnetix Inc.), Michihiro Kawanishi (Toyota Technological Institute)

10:50 – 11:10
A Diffusion Model for Active Magnetic Bearings in Large Turbomachinery
Michael K. Swann, Waukesha Magnetic Bearings, Alexey P. Sarichev, NPP VNIEEM
Eiji Tsunoda, Yokohama Engineering Services

- A study of the adoption rate of AMB technology into the large turbomachinery industry
- A brief history of applications to large compressors
- Adaptation of the well recognized Bass Diffusion Model
- Solution of the Bass equation using Monte Carlo simulation
- A prediction of future adoptions

11:10 – 11:30
Long-term operation of an AMB-supported coolant pump in a lignite-fired power station - results and operational experience -
F. Worlitz and T. Rottenbach
Institute of Process Technology, Process Automation and Measuring Technology, University of Applied Sciences Zittau/Goslar

- Conversion of a coolant pump to completely active magnetic bearings
- Installing and putting into operation in a power station
- Operational experience under realistic conditions
- Presentation of selected operating modes
- Diagnosis of the rotating machine and cooling water system components
- Online determination of bearing loads during operation

11:30 – 11:50
Study on Stability of Steel Strip under the Electromagnetic Shape Controller
A. Inoue1, H. Fujioka2, S. Morii3 and M. Komori4
1 Mitsubishi Heavy Industries, Ltd. 2 Mitsubishi-Hitachi Metals Machinery, Inc. 3 MHI Solution Technologies co., Ltd. 4 Kyushu Institute of technology

- In a steel process line, shape controllers of steel strip using electromagnets are important devices for improving strip quality and line speed.
- It is necessary to avoid a static instability phenomenon by negative spring of the electromagnet, and a spill-over phenomenon by the high gain of the control system in this device.
- This paper discusses the static instability phenomenon and the spill-over phenomenon.

11:50 – 12:10
The Application of Active Magnetic Bearing Spindle On High-speed And Precise Grinding Machine
Shujuin Liu1, Zhongguo Bian1, Wentao Yu1 and Eric Maslen2
1 Dept. of Electric Eng., Shandong Univ., China, 2 Dept. of Mechanical Eng., Univ. of Virginia, USA

- The application of AMB spindle on the high-speed precision grinding machine
- Active magnetic bearing spindle grinder
- For the work reported here, we have used a combination ceramic grinding wheel: CBN, granularity 60, speed limit of 70m/s, and diameter of 25mm.
- The workpiece finished using the active magnetic bearings spindle grinder
- The workpiece roundness quality produced by this grinder exhibits roughness of less than 0.4 um, a circular error of less than 4 um: the higher the speed of workpiece rotation, the smaller the error.

Map of Room Layout:
- Upper floor: Rooms A, B, C
- Ground floor: Room A

27
**Numerical Investigation of AMB Supported Rotor Interaction with Auxiliary Bearings**

L. Xie1, R. Nordmann1 and B. Aeschlimann2

1Dept. of Mechatronics in Mech. Eng., TU Darmstadt, 2Mecos Traxler AG

- Introduction
- Test rig description
- Detailed nonlinear system model
- Equations of motion of the system
- Hertzian nonlinear contact model
- Numerical simulation and results discussion
- Conclusion

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**Simulation-Based Controller Design for an Active Auxiliary Bearing**

Lucas Ginzinger, Heinz Ulbrich

Institute of Applied Mechanics, Technical University Munich, Germany

- New approach to control a rubbing rotor
- Control force indirectly via aux. bearing only during rubbing
- Simulation environment is used for controller development
- Successful exp. verification • avoidance of backward whirling
- Reduction of contact forces and rotor deflection

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**Compressor Surge Control with AMB Actuation**

Se Young Yoon1, Zongli Lin1, Kin Tien Lim2 and Paul E. Alitare2

1Department of Electrical and Computer Engineering
2Department of Mechanical and Aerospace Engineering
University of Virginia

- Compressor surge control through impeller tip clearance modulation using active magnetic bearings
- Pressure ratio is used for feedback
- Nonlinear feedback laws designed in the absence of AMB dynamics fail not stabilize surge
- Robust control is used to compensate AMB dynamics
- Test rig is currently in operation

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**A Novel Hysteresis Current Control Strategy for Switching Power Amplifiers in AMBs**

Zhou Dan, Zhu Changsheng

College of Electrical Engineering, Zhejiang University, China

- A novel double band hysteresis current control method is proposed, where an additional hysteresis band is brought in the conventional hysteresis current control method.
- The behaviours of amplifier with the proposed current control systems are studied in simulation and experiments.
- The current ripple for the double band hysteresis current control method is compared with conventional hysteresis current control method.
TRADE OFFS IN LQ/LTR CONTROL DESIGNS FOR MIMO AMB SYSTEMS

R. P. Jastrzębski, R. Pöllänen
Dept. of Electrical Eng., Lappeenranta Univ. of Technology, Finland

- The genetic algorithm is applied to evaluate the design tradeoffs of LQ, LQ/LTR, PID, and PI/PD controllers in the MIMO AMB system.
- The credible comparison of controllers by using frequency response methods is shown.
- The equivalent controllers are achieved when using the genetic algorithm.
- The decentralized controllers are less liable to tuning with respect to the trade-offs at higher and lower frequencies, than the model based controllers.

Robust control against disturbance model uncertainty in AMB systems

S. Dietz¹, H. M. N. K. Balini¹ and C. W. Scherer¹
¹Dept. of Mechanical Eng., TU Delft, The Netherlands

- Control design to reject disturbances at operating speed.
- Small variations in operating speed lead to uncertainty in the disturbance frequency.
- Novel robust control design procedure for closed loop performance.
- Singular value plots show increased attenuation levels.

OBSERVER-BASED UNBALANCE COMPENSATION IN LQ CONTROL OF AMBS

R. P. Jastrzębski, R. Pöllänen
Dept. of Electrical Eng., Lappeenranta Univ. of Technology, Finland

- The full-order observer-based UFRC with the parameters scheduled according to the rotational speed is presented.
- The applied gain scheduling provided the optimal UFRC for variable speed.
- The controller could reject either unbalance forces or vibrations of magnetic forces.
- In the case of unbalance force cancellation, the pole placement method occurred to be less robustly stable than the optimal solution, with respect to the residual dynamics of the second flexible mode.

A Novel Force Feedback Controller for Magnetic Bearings

Xiaofei Chen, Kun Liu, Kai Xiao
Col. of Astronautics and Material Eng., National Univ. of Defense Tech.

- A PID controller with additional force feedback is discussed, and better performance is achieved.
- Influence of disturbing forces is compensated by direct feedback of the force.
- Dynamic response of power amplifier is improved.
- Provides an idea to utilize rotor’s acceleration and velocity of disturbed translation.
- Magnetic field changes corresponding to disturbing forces are measured by hall components.
Self-Bearing (Bearingless) Motors III
11:00 – 12:20, Aug. 29, 2008 (FRI), Room B
Co-Chairs: Domingos David (Fluminense Federal University), Yohji Okada (Ibaraki University)

11:00 – 11:20
5-DOF Controlled Self-Bearing Motor
T. Ishikawa¹, K. Matsuda¹, T. Masuzawa¹, and R. Kondo¹
¹Dept. of Mechanical Eng., Ibaraki University

- A novel 5-DOF actively controlled self-bearing motor is developed to achieve smaller size and higher performance.
- Radial control performance of the developed self-bearing motor is evaluated. Radial current stiffness: 15 N/A
- Settling time for the impulse: 0.03 sec
- Oscillation amplitude: < 0.05 mm.
- The developed 5-DOF self-bearing motor displays sufficient radial position controllability.

11:20 – 11:40
Digital Optimal Control of a Bearingless Machine
W. Kauss¹, A. Gomes¹, R. Stephan¹ and D. David²
¹Dept. of Electrical Eng. of UFRJ, ²Dept. of Mechanical Eng. of UFF (Brazil)

This paper presents experimental results of a bearingless machine controlled with a Linear Quadratic Regulator (LQR). The laboratory prototype, the mathematical model and the establishment of a coupled and decoupled feedback control law will be explained. The computational time of these algorithms will be compared with that of a simple PD control.

11:40 – 12:00
In this study, a novel self-bearing motor is proposed using a slotless distribution winding.
- The motor torque and bearing force are derived analytically, and a control method is discussed.
- Experimental results show that the proposed self-bearing motor has high potential for high-speed rotation.

12:00 – 12:20
Independent Control of Torque and Radial Force in Bearingless Switched Reluctance Motors
X. Cao, Z.-Q. Deng, G. Yang and X.-L. Wang
Nanjing University of Aeronautics and Astronautics, China

- Modified model with Maxwell stress tensor method used in the work.
- Independent control scheme demonstrated with FE analysis.
- Levitation currents calculating algorithm.
- Torque ripple reduction with FE analysis.
- Experiment control block.
- Experiment results.

Experimental Setup
Schematic of Slotless SBM
Prototype d=31mm, b=23mm
Computational times in µs
Radial current stiffness: 15 N/A
Settling time for the impulse: 0.03 sec
Oscillation amplitude: < 0.05 mm.

Experimental results show that the proposed self-bearing motor has high potential for high-speed rotation.

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- Levitation currents calculating algorithm.
- Torque ripple reduction with FE analysis.
- Experiment control block.
- Experiment results.
Magnetic Suspensions III
11:00 – 12:20, Aug. 29, 2008 (FRI), Room C
Co-Chairs: Paulides Johannes (Eindhoven University of Technology), Koichi Oka (Kochi University of Technology)

11:00 – 11:20

Zero Power Control for Permanent Magnetic Suspension System
F. Sun and K. Oka
Dept. of Intelligent Mechanical System Eng., Kochi University of Technology
This paper describes a kind of permanent magnetic suspension system, which consists mainly of a permanent magnet, an actuator and sensors. This magnetic suspension system is based on a zero power control method, which results in almost no power consumption in the equilibrium state. A spring was installed in the suspension device to counterbalance the actuator force on the mass gravitation in the equilibrium position. An integral feedback loop was used in the controller to make the actuator current zero.

11:20 – 11:40

Experimental verification of look-up table based real-time commutation of 6-DOF planar actuators
J. de Boeij and E. Lomonova
Dept. of Electrical Eng., Eindhoven Univ. of Tech., The Netherlands
- 6-DOF magnetic suspension and propulsion, long-stroke
- Real-time commutation incl end-effects
- Experimental verification, data shown
- Over-actuated (81 coils)
- Submicron accuracy
- 184 microseconds calculation time
- Working prototype shown in movie

11:40 – 12:00

Experimental Study on the Basic Characteristic of Flux-Path Control Magnetic Suspension
M. Furutachi, S. Imao, M. Takasaki, Y. Ishino and T. Mizuno,
Dept. of Mechanical Eng., Saitama University
- 3-D attractive forces acting on a floator are measured.
- Modeling is carried out based on the measurements.
- Positioning in the vertical direction is achieved.

12:00 – 12:20

Geometrical Design for a Large Magnetic Supporting System Considering Coupling Effect
Tian Jie, Wang Yong, Zhao Han, Zhang Ping, Huang Wenting
School of Machinery and Automobile Engineering, Hefei University of Technology
- Magnetic mechanism is one of the main directions among a variety of applications to achieve supporting function by electromagnetic force, but the design method still needs continuous improvement.
- This paper combines the method of magnetic-circuit and analysis of magnetic field against the present design methods’ defects.
- A large-scaled spindle is studied in this paper.
- The design result has proven the feasibility of a field-circuit integrated way considering coupling effect in magnetic mechanism and electromagnetic parameter design.
Contact-Free Bearings for Flywheels II  
13:20 – 14:40, Aug. 29, 2008 (FRI), Room A  
Co-Chairs: Jose Martin Echeverria (University of Navarra), Satoru Sakai (Chiba University)

13:20 – 13:40  
**A NOVEL PASSIVITY BASED CONTROL WITHOUT CONVENTIONAL CROSS-FEEDBACK**  
S. Sakai¹, K. Kuriyama¹ and K. Nonami¹  
¹Dept. of Mechanical Eng., Chiba University, Japan
- Passivity based control without conventional cross-feedback based on the structural properties of the flywheel  
- The local and global stabilization of some PID controllers without nonlinearity canceling against the gyroscopic effect  
- Simulation and experimental results

13:40 – 14:00  
**An Approach to a 3-pole Active Magnetic Bearing System fed by a Matrix Converter**  
J. Vadillo, J.M. Echeverria, I. Elosegui and L. Fontan  
CEIT and Tecnun (University of Navarra)
- MATLAB/Simulink model for a 3-pole radial magnetic bearing system (MBS) that is fed by a Matrix Converter (MC)  
- Comparison between supplying the MBS by means of a regular Voltage Source Inverter (Rectifier-dc_link-Inverter) model and a MC model  
- MC improvements can be observed in the source current  
- Feasibility of using a MC for this kind of systems is proved in simulation

14:00 – 14:20  
**Attitude Stabilization Control of AMB-Flywheel Supported by Two-Axes Gimbals**  
K Kuriyama, K Nonami, B RACHMANTO  
Dept. of Electronics and Mechanics, Chiba University
- Using a flywheel energy storage system using the magnetic bearing with the gimbal system on the vehicle.  
- Deriving the equation including not only flywheel but also gimbals.  
- Verification of above equation and the effect of the gimbal system by comparison the simulation and the experiment.

14:20 – 14:40  
**An Approach to a 3-pole Active Magnetic Bearing System fed by a Matrix Converter**  
J. Vadillo, J.M. Echeverria, I. Elosegui and L. Fontan  
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- MATLAB/Simulink model for a 3-pole radial magnetic bearing system (MBS) that is fed by a Matrix Converter (MC)  
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**Floor Plan**
- Upper floor  
  - Room A  
- Ground floor  
  - Room A  
  - Entrance
A Supercritical 250 kW Industrial Air Compressor Prototype
Erkki Lantto, Ville Tommila
High Speed Tech Oy Ltd

- 250 kW, 320 Hz induction motor with magnetic bearings
- Issues with passing the first bending critical speed
- Synchronous response control (SRC)
- Position controller synthesis
- “Negative damping” SRC
- Measurements

Automatic Thermal Expansion Compensation of The AMB Spindle in Precision Grinding Machine
Bin Bian1, Shuqin Liu1, Deguang Li1 and Eric Maslen2
1Dept of Electric Eng., Shandong Univ., China, 2Dept of Mechanical Eng., Univ. of Virginia, USA

- Compensation of the grinding head position error due to this temperature rise is particularly important.
- Design of the temperature detection component
- Modeling and analyzing of the relationship between temperature rise and rotor posture
- The adjustment of grinding head posture in digital signal processor
- Experiments proved that this algorithm could compensate the thermal expansion of the AMB spindle successfully

Design and Manufacturing of a 70KW, 36000 rpm Milling Spindle
A. Izpizua1, X. Almandoz2, M. San Martin1, D. Cantero1 and I. Perez1
1Mechatronics & Precision Engineering Dept., Fundacion Tekniker-IK4
2Goiadale High Speed

- 70kW and 36000 rpm design issues
- Spindle design
  - Configuration & force distribution design
- Control electronic design
- Damping analysis for high speed machining
  - Ball bearing spindle comparison
  - Signals estimation for damping

PRELIMINARY TESTS FOR THE HTR-10 HELIUM CIRCULATOR WITH ACTIVE MAGNETIC BEARINGS
Yu Suyuan
Institute of Nuclear and New Energy Technologies, Tsinghua University, Beijing, China

- Introduction
- HTR-10 Helium Circulator on Service
- AMB Helium Circulator
- Preliminary Tests for AMB Circulator
- Conclusions

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13:20 – 13:40

13:40 – 14:00

14:00 – 14:20

14:20 – 14:40
Active Axial Electromagnetic Damper

A. Filatov¹, L. Hawkins¹, V. Krishnan², B. Lam²
¹Calnetix Inc., ²Direct Drive Systems Inc.

- A design of an Active Axial Electromagnetic Damper is presented
- The primary application for the damper is in rotating machines with Passive Axial Magnetic Bearings
- The key feature of the damper is a novel actuator with a flux feedback
- Advantages of the proposed actuator:
  ✓ Virtually no axial negative stiffness
  ✓ Linear relationship between the output force and the control command
  ✓ Uniform frequency response over a wide frequency range

This 1MW 15000RPM motor on magnetic bearings will be the first application for the proposed damper.

Self-Sensing of non-laminated axial AMB’s: Modelling & Validation

R. Herzog¹, S. Vullioud¹, Roman Amstad², Gorka Galdos², Philippe Muelhaupt², Roland Longchamp², ¹HEIG-VD, ²EPFL Switzerland

- Low Order Nonlinear State Space Model
- Eddy Current Modelling by RL Ladder Network
- Dynamic Hysteresis (Bertotti Model)
- Bearing Current Underlinear w.r.t. Voltage
- Experimental Validation on Test Rig
Magnetic Actuator II
15:10 – 16:30, Aug. 29, 2008 (FRI), Room A
Co-Chairs: Xiaodong Lu (The University of British Columbia), Toru Masuzawa (Ibaraki University)

15:10 – 16:10

**LINEAR MAGNETIC BEARING/ACTUATOR DESIGN AND PROTOTYPE FOR PRECISION SPINDLES**

X.-D. Lu¹, M. Paone¹, I. Usman¹ and A.H. Slocum²

¹Department of Mechanical Engineering, UBC
²Department of Mechanical Engineering, MIT

- Radially biased thrust bearing/axial actuator to achieve linear force characteristics
- Magnetic actuator integrated with aerostatic journal bearing to achieve combined precision rotary-axial motion
- Axial stroke: 1 mm
- Axial force: 300 N (continuous) and 600 N (peak)
- 1500 Hz closed-loop bandwidth
- 5 nm RMS positioning noise

**WIDE GAP MAGNETIC BEARING SYSTEM FOR A MAGNETICALLY SUSPENDED CLEAN PUMP**

H. Kurosu¹, T. Masuzawa¹, A. Katoh¹, K. Suzuki¹, H. Onuma², K. Kakihara²

¹Dept. of Mechanical Eng., Ibaraki University, ²IWAKI CO., LTD.

- A new hybrid magnetic bearing and motor system for magnetically suspended clean pumps with wide air gaps has been developed.
- The design optimization method has been developed based on magnetic equivalent circuit technique, genetic algorithm (GA) and three dimensional magnetic field analysis.
- The designed HMB bearing and motor system has an outer diameter of 100 mm, a length of 140 mm, and air gaps of 3.5 mm.
- The optimized system produces a target attractive force of 20 N with an excitation current of 0.5 A and the ratio of force to excitation current is 40 N/A.

15:50 – 16:10

**DESIGN AND ANALYSIS OF NEW PERMANENT MAGNET BIASED HETEROPOLAR MAGNETIC BEARINGS**

Uhn Joo Na, Hyun Ok Kang, Dong Dae Lee and Kyung Hwan Seo

Dept. of Mechanical Eng., Kyungnam Univ., Korea

- A novel permanent magnet biased heteropolar type magnetic bearing is developed.
- Magnetic bearing has a unique biasing and control paths such that the fluxes flow in the circumferential direction.
- This design makes the bearing axially thin and does not require a dead pole plane.

16:10 – 16:30

**DESIGN AND REALIZATION OF MAGNETIC SUSPENDED DEVICE BASED ON EDGE EFFECT**

Huachun Wu¹, Xiaoguang Wang², Li Wei³ and Yefa Hu²

¹School of Mechanical Engineering, Wuhan Univ. of Technology
²Dept. of Mechanical Eng., Wuhan University
³Dept. of Mechanical Eng., Wuhan University

- The analysis of edge effect.
- System Compositions and Work Principle.
- Control mathematical model of magnetic suspended disk.
- Control system design.
- Analysis of experiment result.
Modeling and Identification II
15:10 – 16:30, Aug. 29, 2008 (FRI), Room B
Co-Chairs: Raoul Herzog (EIVD Yverdon), Satoru Fukata (Kyushu University)

15:10 – 15:30
Overcoming of High Centrifugal Forces in a 5 DOF Micro AMB Gyroscope
T. Bosgiraud, D. Chapuis, F. Barrot and H. Bleuler
Laboratoire de Systemes Robotiques
Ecole Polytechnique Federale de Lausanne (Switzerland)

• Realization of a 5 DOF Micro AMB gyroscope.
• Counteracting the effect of unbalance effects by means of H \(\infty\) control based on the GST weighting scheme.
• Improvement of the trajectory tracking and of the disturbance rejection thanks to the adjunction of an explicit integrative part to the H \(\infty\) controller.
• Tremendous improvement in the quality and stability of the angular velocity measurement.

15:10 – 15:30
Identification and Modeling of AMB Rotor System Using Complex Lead and Lag Compensator Structures
K. Hynynen, R. Jastrzebski, R. Pöllänen
Dept. of El. Eng., Lappeenranta University of Technology, Finland

• Purpose of the study is to identify the flexible modes of the rotor using nonparametric methods
• Parametric transfer function model is determined using complex lead and lag compensator structures
• Major advantage of proposed method is a graphical presentation that makes it very illustrative and simple to use

15:30 – 15:50
A Model of Magnetic Reluctance of Cylindrical Solid Iron-Cores
Satoru Fukata
Faculty of Design, Kyushu University

• Electromagnet having a cylindrical solid iron-core
• Simplification with a high core without ends
• Analytical solution of 3-dimensional magnetic field with fixed air-gap using Laplace transform
• Magnetic reluctance in frequency domain
• Approximation without Bessel functions
• Check with experimental data

15:50 – 16:10
Parameterized electromechanical model for magnetic bearings with induced currents
V. Kluyskens\(^1\) and B. Dehez\(^1\)
\(^1\)Cerem, Université Catholique de Louvain, Belgium

• Electromechanical model integrating electromagnetic forces and rotating machinery aspects
• Induced currents
• Inductive and resistive effects
• Skin effect
• Stability study
• Validated on existing semi-passive magnetic bearing.

16:10 – 16:30
Identification and Modeling of AMB Rotor System Using Complex Lead and Lag Compensator Structures
K. Hynynen, R. Jastrzebski, R. Pöllänen
Dept. of El. Eng., Lappeenranta University of Technology, Finland

• Purpose of the study is to identify the flexible modes of the rotor using nonparametric methods
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Self-Sensing (Sensorless) Techniques II
15:10 – 16:30, Aug. 29, 2008 (FRI), Room C
Co-Chairs: Shuqin Liu (Shandong University), Hirochika Ueyama (MUTECS Inc.)

15:10 – 15:30

A PHASE MODULATION SELF-SENSING TECHNOLOGY
OF ACTIVE MAGNETIC BEARINGS USING A HIGH
FREQUENCY VOLTAGE INJECTION METHOD
Young Ho Park¹, In Hwang Park², Hee Doh Jang¹ and Dong Chul Han¹
¹School of Mech. & Aero. Eng., Seoul National Univ., ²BK21 School for

- A high frequency voltage injection method
- A phase modulation technology and a signal processing algorithm
- Frequency response of the proposed position estimator
- Magnetic levitation and disturbance rejection using the proposed algorithm

15:30 – 15:50

Test Bench for Three Phase Permanent Magnet biased
Radial AMBs with a Sensorless Control Strategy
based on INFORM method
Matthias Hofer, Manfred Schroedl
Inst. of Electrical Drives and Machines, Vienna University of Technology

- Test Bench for Sensorless Control
- Permanent Magnet biased AMB
  - Hybrid Magnetic Bearing (HMB)
- Basic idea of the INFORM – method
- Short description of the test stand
- First results of INFORM method
- Goal: Optimization and Sensorless Control of the HMB prototype

15:50 – 16:10

A Coupled Reluctance Network
Approach to Self-sensing
Eugén O. Ranft¹, George van Schoor¹
¹Dept. of Electrical Eng., North-West Univ.

- Amplitude modulation self-sensing approach
- Switching amplifier ripple as high frequency source
- Coupled reluctance network model - MIMO parameter estimation self-sensing scheme
- Alleviate problems associated with self-sensing: magnetic cross-coupling, eddy currents and saturation.
- System sensitivity levels satisfactory for long term operation are achieved.

16:10 – 16:30

Upper floor

Ground floor

Room A

Entrance