The 11th International Symposium on Linear Drives for Industry Applications

Osaka, Japan, September 6-8, 2017
Sponsored by

Industry Applications Society, The Institute of Electrical Engineers of Japan (IEEJ IAS)

Technical sponsored by

The IEEE Industry Applications Society (IEEE-IAS)
IEEE Tokyo/Japan Joint Sections Industry Applications Society Chapter

Co-sponsored by

Osaka Institute of Technology

In cooperation with

The Japan Society of Mechanical Engineers
The Japan Society of Applied Electromagnetics and Mechanics
The Magnetic Society of Japan
The Society of Instrument and Control Engineers

Financial Support

Research Foundation for the Electrotechnology of Chubu
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Ladies and gentlemen, thank you for joining us.
We are pleased to welcome you to Osaka and to the 11th International Symposium on Linear Drives for Industry Applications (LDIA 2017).
First of all, I would like to thank all the committee members and reviewers for their invaluable assistance in supporting this conference.
The goal of the symposium is to bring together researchers from both academia and industry from all over the world, and to discuss present research and development activities and future prospects related to the linear drives for industry applications.
We hope that this conference will provide a good opportunity for your research goals. We wish you to foster your network of friends and colleagues.
This year the conference is held in Osaka city, center city of the western Japan, the place to gather information, technology, culture and delicious dishes. We wish you an enjoyable stay in Japan and a productive and pleasant time at LDIA2017.
Conference Chair
Prof. Toshimitsu Morizane (Osaka Institute of Technology, Japan)

International steering committee

Chairperson
Prof. H. Ohsaki, Japan

Members
J. Driesen, Belgium          D.H. Kang, Korea
A.C. Ferreira, Brazil       E. Lomonova, Netherlands
J.X. Shen, China            I. Boldea, Romania
L.M. Shi, China             C. Sadarangani, Sweden
Q. Lu, China                A. Cassat, Switzerland
J. P. Yonnet, France        Y. Perriard, Switzerland
A. Binder, Germany          A. Rufer, Switzerland
W.R. Canders, Germany       F.J. Lin, Taiwan
K. Hameyer, Germany         M.C. Tsai, Taiwan
T. Higuchi, Japan           F. Eastham, UK
J. Kitano, Japan            J. Wang, UK
T. Koseki, Japan            Z.Q. Zhu, UK
T. Mizuno, Japan            J. Gieras, USA
J.P. Hong, Korea            S. Gurol, USA
H.K. Jung, Korea            D. Trumper, USA

Organizing Committee
Chair: Prof. Tsutomu Mizuno (Shinshu University, Japan)

Technical Program Committee
Chair: Prof. Keisuke Fujisaki (Toyota Technological Institute, Japan)
Vice chair: Prof. Shunsuke Ohashi (Department of Electrical and Electric Engineering, Kansai University, Japan)

National Steering Committee
Chair: Prof. Toshimitsu Morizane (Osaka Institute of Technology, Japan)
Vice chair: Prof. Shunsuke Ohashi (Department of Electrical and Electric Engineering, Kansai University, Japan)
**Conference information.**

**Company-exhibition:** The Company-exhibition is held at Room P. It starts at 9:00 on 7th September and ends at 15:30 on 8th September.

1) Central Japan Railway Company  
2) Applied Electronics Corporation  
3) CYBERNET SYSTEMS CO., LTD.  
4) Hottinger Baldwin Messtechnik GmbH (Spectris Co., Ltd.)

**Welcome Party:** Welcome party starts from 18:00 at Room P, 2nd Floor, OIT UMEDA TOWER (Conference venue) on 6th September, 2017. Only the registered persons (regular, student, accompanying) and the designated persons can attend the welcome party. Please show your nametag to the staffs at the entrance of the Room P.

**Coffee break:** Coffee is served during the coffee break time at Room P. It is prohibited to bring any drinks and foods inside the Hall.

**Authors’ breakfast and Lunch:** The conference authors’ breakfast and the conference lunch are NOT provided. We will give you the map of the restaurants at the registration desk. Please enjoy your lunch at the restaurants. There are a lot of restaurant around conference venue. The cost depends on the restaurant and it may cost from JPY 500 to JPY 1,500. In Japan, tips are not necessary anywhere, even at hotel and restaurants.

The conference venue, OIT UMEDA TOWER has the restaurant on 21st floor. You have lunch for JPY 600. You can get to the restaurant by only the elevator (lift) for the restaurant on 1st floor.

**Banquet:** Banquet starts from 18:00 on 7th September, 2017 at the 21F restaurant of the conference venue. Only the regular registration participants, the student registration participants, the registered accompanying persons and the designated persons can enter the restaurant. You can get to the restaurant by only the elevator (lift) for the restaurant at 1st floor. Please take the elevator to the restaurant. Our staffs invite you to the elevator at the 1st floor. Please contact to them.

**Wifi service:** Conference Free Wifi service is NOT provided. Please use eduroam, public free Wifi service or bring your own device for the Wifi.

**Electricity service and Rest Area:** We prepare for the several electrical outlets and tables at Room P. Sorry for inconvenient, but the number of the outlets is limited.

In Japan, plug type is A (two-pin plug) and the voltage is 100V. The frequency is 60Hz in Western Japan (including the conference venue) and 50 Hz in Eastern Japan.
## Program at glance

**Date:** 7th Sep.(Thu)

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<td>9:00-9:30</td>
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<td><strong>Hall</strong></td>
<td><strong>Prof. T. Morizane</strong></td>
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<td>9:30-10:10</td>
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<td><strong>Prof. Y. Kawazoe</strong></td>
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<td><strong>Origin of Magnetism - 90 years of misunderstanding -</strong></td>
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<td><strong>Prof. K. Fujisaki</strong></td>
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<td>10:25-12:30</td>
<td><strong>Oral session:</strong></td>
<td><strong>Room 1</strong></td>
<td><strong>Prof. Y. Perriard</strong></td>
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<td><strong>Oral 1A</strong></td>
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<td><strong>Prof. T. Hirayama</strong></td>
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<td>14:00-15:40</td>
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<td><strong>Prof. H. Suzuki</strong></td>
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<td><strong>Prof. J. Kluehspeis</strong></td>
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<td><strong>Prof. C. B. Lee</strong></td>
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<td>16:00-17:15</td>
<td><strong>Oral session:</strong></td>
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<td><strong>Prof. Y. Li</strong></td>
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<td><strong>Prof. N. Niguchi</strong></td>
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<td><strong>Linear Motor 2</strong></td>
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<td><strong>Electromagnetic and Force Fields</strong></td>
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<td><strong>Keynote</strong>&lt;br&gt;Applications of Linear Machinery in Public Transport&lt;br&gt;Location: Hall&lt;br&gt;Prof. T. Koseki&lt;br&gt;Chair: Prof. T. Morizane</td>
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<td>10:25-12:30</td>
<td><strong>Oral session:</strong>&lt;br&gt;Oral 3A&lt;br&gt;Levitation Technologies&lt;br&gt;Location: <strong>Room 1</strong>&lt;br&gt;Chair: Prof. E. A. Lomonova&lt;br&gt;Chair: Prof. S. Ueno</td>
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<td><strong>Oral session:</strong>&lt;br&gt;Oral 3B&lt;br&gt;Transportation&lt;br&gt;Location: <strong>Room 2</strong>&lt;br&gt;Chair: Prof. Q. Lu&lt;br&gt;Chair: Mr. J. Kitano</td>
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<td>14:00-15:15</td>
<td><strong>Oral session:</strong>&lt;br&gt;Oral 4A&lt;br&gt;Trends And New Developments of Linear Drives&lt;br&gt;Location: <strong>Room 1</strong>&lt;br&gt;Chair: Prof. N. Misron&lt;br&gt;Chair: Prof. T. Higuchi</td>
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<td><strong>Oral session:</strong>&lt;br&gt;Oral 4B&lt;br&gt;Control Methods for Linear Drives&lt;br&gt;Location: <strong>Room 2</strong>&lt;br&gt;Chair: Prof. L. M. Shi&lt;br&gt;Chair: Prof. T. Mizuno</td>
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<td><strong>Oral session:</strong>&lt;br&gt;Oral 5B&lt;br&gt;Materials&lt;br&gt;Location: <strong>Room 2</strong>&lt;br&gt;Chair: Prof. C. B. Part&lt;br&gt;Chair: Dr. Y. Shindo</td>
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<td>17:00-17:30</td>
<td><strong>Closing</strong>&lt;br&gt;Location: Hall&lt;br&gt;Chair: Prof. S. Ohashi</td>
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Access Map

Conference Venue: **OIT UMEDA TOWER**
Umeda Campus, Osaka Institute of Technology (OIT)
1-45 Chayamachi kita-ku, Osaka city, Osaka 530-0013, Japan
Keynote speech

Keynote speech 1
Origin of Magnetism
- 90 years of misunderstanding -
Time: Sep. 7th: 9:30-10:10
Location: Hall, 3rd Floor
Prof. Yoshiyuki KAWAZOE
Professor in Tohoku University

Keynote speech 2
Applications of Linear Machinery in Public Transport
Time: Sep. 8th: 9:30-10:10
Location: Hall, 3rd Floor
Prof. Takafumi KOSEKI
Professor in University of Tokyo
Oral Session

Oral 1A: Linear Motor 1
Time: Sep. 7th: 10:25-12:30
Location: Room 1
Chair: Prof. Y. Perriard (EPFL)
Chair: Prof. T. Hirayama (Kagoshima Univ.)

LM-1 High-Force Linear Iron-core Fine-tooth Motor
Jun Young Yoon, Jeffrey H. Lang, David L. Trumper
Department of Mechanical Engineering, Massachusetts Institute of Technology, USA

LM-2 Considerations in the Numerical Design for the Armatures of LIM-type Eddy-Current Rail Brakes
Hiroshi Yoda, Yasuaki Sakamoto
Maglev Systems Technology Division, Railway Technical Research Institute, Japan

LM-3 Comparison of Direct and Indirectly Liquid-cooled Coreless Linear Actuators with Multi-layer Coils
T.A. van Beek, J.W. Jansen, B.L.J. Gysen, E.A. Lomonova
Electromechanics and Power Electronics, Eindhoven University of Technology, The Netherlands

LM-4 Experimental Investigation of a Partitioned Stator Flux Reversal Permanent Magnet Linear Machine
Z.Q. Zhu¹, A. L. Shuraiji¹, ², Q. F. Lu³, Yihua Yao³
¹Department of Electronic and Electrical Engineering, University of Sheffield, UK,
²Electromagnetic Engineering Department, University of Technology, Iraq,
³Institute of Electrical Engineering, Zhejiang University, P.R. China

LM-5 Comparative Study of Two Permanent Magnet Linear Machines
Z.Q. Zhu¹, Ahlam L Shuraiji¹, ²
¹Department of Electronic and Electrical Engineering, University of Sheffield, UK,
²Electromagnetic Engineering Department, University of Technology, Iraq
Oral 1B: Linear Actuators
Time: Sep. 7th: 10:25-12:30
Location: Room 2
Chair: Prof. K. Hameyer (RWTH Aachen Univ.)
Chair: Prof. T. Mizuno (Shinshu Univ.)

LA-1 Design and Analysis of a Linear Oscillatory Actuator for Active Control Engine Mounts
Insung Choi, Katsuhiro Hirata, Noboru Niguchi
Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Japan

LA-2 Active Vibration Control of Drum Type of Washing Machine using Linear Oscillatory Actuator
Yuki Suzuki, Katsuhiro Hirata, Masayuki Kato
Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Japan

LA-3 Prediction and Prevention of Losing Steps in a Helical Teethed Linear Actuator
Masahiko Sakai¹, Katsuhiro Hirata¹, Yoshihiro Nakata²
¹Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Japan,
²Department of Systems Innovation, Graduate School of Engineering Science, Osaka University, Japan

LA-4 Development of a Noncontact Impact Relieving Device of a Falling Object by Electromagnetic Impulsive Force
Satoshi Ueno, Takahiro Hiroi, Toshiro Higuchi, Changan Jiang
Ritsumeikan University, Japan

LA-5 Performance Improvement of a Linear Permanent Magnet Gear
Xin-Yuan Xu, Yong-Tao Tan, Yun-Chong Wang, Jian-Xin Shen
Department of Electrical Engineering, Zhejiang University, China
Oral 2A: Linear Motor 2
Time: Sep. 7th: 16:00-17:15
Location: Room 1
Chair: Prof. Y. Li (Chinese Academy of Sciences)
Chair: Prof. N. Niguchi (Osaka Univ)

LM-6 Design Analysis of a Segment Type Linear Switched Reluctance Motor
Tsuyoshi Higuchi¹, Yuichi Yokoi¹, Takashi Abe¹, Naoki Yasumura¹,
Yasuhiro Miyamoto², Shogo Makino²
¹Nagasaki University, Japan,
²Yaskawa Electric Corporation, Japan

LM-7 Consideration of Linear Synchronous Motor Characteristic in Curved Part
Shogo Makino¹, Masanobu Kakihara¹, Masayuki Hirayama¹, S. Tanaka¹,
Toru Shikayama¹, Tsuyoshi Higuchi², Takahi Abe²
¹Yaskawa Electric Corporation, Japan,
²Nagasaki University, Japan

LM-8 Development of High-Acceleration Linear Motor System using the Transient Loss Evaluation
Yu Hasegawa, Yasuaki Aoyama
Research and Development Group, Hitachi, Ltd., Japan
Oral 2B: Electromagnetic and Force Fields
Time: Sep. 7th: 16:00-17:15
Location: Room 2
Chair: Prof. Z. Q. Zhu (U. of Sheffield)
Chair: Dr. T. Murai (Central Japan Railway)

**EM-1** Modeling and Experimental Validation of Field Distributions due to Eddy Currents in Slitted Conducting Plates
C.H.H.M. Custers, J.W. Jansen, E.A. Lomonova
Electromechanics and Power Electronics, Eindhoven University of Technology, The Netherlands

**EM-2** Analytical Modelling Techniques for Thrust Force Calculation of a Permanent Magnet Linear Motor
E.A. Lomonova, S.R. Aleksandrov, D.C.J. Krop, D.T.E.H. van Casteren, T.T. Overboom,
Electromechanics and Power Electronics Group, Department of Electrical Engineering, Eindhoven University of Technology, The Netherlands

**EM-3** Dynamical Model of an Electromagnet by Cauer Ladder Network Representation of Eddy-Current Fields
Yuji Shindo¹, Akihisa Kameari², Kengo Sugahara³, Tetsuji Matsuo⁴
¹Kawasaki Heavy Industries, Ltd., Japan,
²Science Solutions International Laboratory, Inc., Japan,
³Faculty of Science and Engineering, Kindai University, Japan,
⁴Graduate School of Engineering, Kyoto University, Japan
Oral 3A:
Levitation Technologies
Time: Sep. 8th: 10:25-12:30
Location: Room 1
Chair: Prof. E. A. Lomonova (Eindhoven UT)
Chair: Prof. S. Ueno (Ritsumeikan Univ.)

LT-1 Magnetically Levitated Planar Positioning Systems Based on Lorentz Forces
Mousa Lahdo¹, T. Ströhla², S. Kovalev¹
¹Department of Information Technology, Electrical Engineering and Mechatronics, University of Applied Sciences Mittelhessen, Germany,
²Department of Mechatronics, Ilmenau University of Technology, Germany

LT-2 Improvement of Average Velocity Error in the HTS Magnetically Levitated Conveyance System
Hayato Sasaki, Takuro Sumida, Yuta Takaki, Shunsuke Ohashi
Department of Electrical and Electric Engineering, Kansai University, Japan

LT-3 Compact Maglev Motor with Full DOF Active Control for Miniaturized Rotary Blood Pumps
Masahiro Osa¹, Toru Masuzawa¹, Ryoga Orihara¹, Eisuke Tatsumi²
¹Ibaraki University, Japan,
²National Cerebral and Cardiovascular Center Research Institute, Japan

LT-4 Zero-Power Control of Flux-path Control Magnetic Suspension System with Flux-interrupting Plates
Takeshi Mizuno, Masaya Takasaki, Masayuki Hara, Daisuke Yamaguchi, Yuji Ishino
Department of Mechanical Engineering, Saitama University, Japan

LT-5 Performance Improvement of a Bearingless Motor by Rotation about an Estimated Center of Inertia
Junichi Asama¹, Tomotaka Shibata¹, Takaaki Oiwa¹, Tadahiko Shinshi², Akira Chiba²
¹Shizuoka University, Japan,
²Tokyo Institute of Technology, Japan
Oral 3B: Transportation
Time: Sep. 8th: 10:25-12:30
Location: Room 2
Chair: Prof. Qinfen Lu (Zheijiang Univ.)
Chair: Mr. J. Kitano (Central Japan Railway)

TP-1  The Development of Criteria for Evaluating Energy Efficiency and the Choice of the Optimal Composition of the Subsystems in the Russian Integral Transit Transport System
B.A. Lyovin¹, A.M. Davydov¹, P.V. Kurenkov¹, I.V. Karapetyants¹, V.G. Shavrov²,
V.V. Koledov², S.V. Fongratovski³, G.G. Malinetskiy³, P.V. Kryukov⁴, B.V. Drozdov²,
Yu.A. Terentiev⁶
¹Russian University of Transport (MIIT), Russia,
²Kotelnikov Institute of Radio-engineering and Electronics of RAS, Russia,
³Keldysh Institute of Applied Mathematics, Russia,
⁴Central Research Institute of Machine Building, Russia,
⁵Institute of Information-Analytical Technology, Russia,
⁶an independent expert

TP-2  Development of Ironless Halbach Permanent Magnet Linear Synchronous Motor for Traction of a Novel Maglev Vehicle
Ke Wang¹,², Qiongxuan Ge¹, Liming Shi¹, Yaohua Li¹,², Zhihua Zhang¹
¹Key Laboratory of Power Electronics and Electric Drive, Institute of Electrical Engineering, Chinese Academy of Sciences, China,
²University of Chinese Academy of Sciences, China

TP-3  Technical Challenges to Realize Energy-Efficient Linear Metros in Japan
Takafumi Koseki¹, Shoichiro Watanabe², Takeru Miura¹, Takeshi Mizuma³,
Eisuke Isobe⁴
¹Department of Electric Engineering and Information Systems, School of Engineering, The University of Tokyo, Japan,
²National Traffic Safety and Environment Laboratory, Japan,
³Department of Advanced Energy, School of New Frontier Sciences, The University of Tokyo, Japan,
⁴Japan Subway Association, Japan
TP-4  Maglev Trends in Public Transport: The Perspectives of Maglev Transportation Systems
Johannes Kluehspies
The International Maglev Board, Germany

TP-5  Development of a Test Stand for Maglev Vehicles Using Hardware-in-the-Loop Simulation
Masashi Kabutomori¹, Toshiaki Murai¹, Shuichiro Ota¹, Yoshiaki Terumichi²
¹Chuo Shinkansen Promotion Division, Central Japan Railway Company, Japan,
²Department of Engineering and Applied Sciences, Sophia University, Japan
Oral 4A:
Trends and New Developments of Linear Drives
Time: Sep. 8th: 14:00-15:15
Location: Room 1
Chair: Prof. N. Misron (U. Putra Malaysia)
Chair: Prof. T. Higuchi (Nagasaki Univ)

TD-1  Novel Oscillatory Actuator for Haptic Device using Principle of Stepper Motor
Masataka Yasukawa, Katsuhiro Hirata, and Masayuki Kato
Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Japan

TD-2  Design of Linear Synchronous Generator Suitable for Free-Piston Engine Linear Generator System
Yuichiro Yamanaka¹, Masami Nirei², Mitsuhide Sato³, Hironobu Murata¹, Yinggang Bu¹, Tsutomu Mizuno¹
¹Shinshu University Faculty Engineering, Japan,
²National Institute of Technology, Nagano College, Japan,
³Nagano Prefectural Institute of Technology, Japan

TD-3  Study of Linear Vernier Motor for Household Automatic Doors
Daichi Kameda, Katsuhiro Hirata, Noboru Niguchi
Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Japan
Oral 4B: Control Methods for Linear Drives
Time: Sep. 8th: 14:00-15:15
Location: Room 2
Chair: Prof. L.M. Shi (Chinese Academy of Sciences)
Chair: Prof. T. Mizuno (Saitama Univ)

CT-1 Fault-tolerant oriented control of modular linear switched-flux permanent magnet machine
Zhiqiang Zeng, Qinfen Lu
College of Electrical Engineering, Zhejiang University, China

CT-2 Examination of a Free-Piston Engine Linear Generator System with Generation Control for High Efficiency
Mitsuhide Sato¹,², Masami Nirei³, Yuichiro Yamanaka¹, Hironobu Murata¹,
Yinggang Bu¹, Tsutomu Mizuno¹
¹Shinshu University Faculty of Engineering, Japan,
²Nagano Prefectural Institute of Technology, Japan,
³National Institute of Technology, Nagano College, Japan

CT-3 Modeling and Control of an Active Magnetic Bearing with Four Poles and Coupled Magnetic Fluxes
Christian. Tshizubu¹, José Andrés Santisteban¹,²
¹Graduate Program in Mechanical Engineering, Universidade Federal Fluminense, Brazil,
²Graduate Program in Electrical and Telecommunications Engineering, Universidade Federal Fluminense, Brazil
**Oral 5A:**
*Other Related Topics and New Technologies*

**Time:** Sep. 8th: 15:30-16:45  
**Location:** Room 1  
**Chair:** Prof. W. Xu (Huazhong U. Science Tech.)  
**Chair:** Prof. T. Nakagawa (Tokyo City Univ.)

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**OT-1 Prototype of Magnetic Energy Harvesting Device as a 3.3 V Battery**  
Genki Itoh¹, Kunihisa Tashiro¹, Hiroyuki Wakiwaka¹, Takao Kumada²,  
Kenichi Okishima²  
¹ Shinshu University, Japan,  
² Fuji Electric Co., Ltd., Japan

**OT-2 Magnetic Field Performance of Round Layout Linear Halbach Array using Cylinder-shaped Permanent Magnets**  
Haruhiko Suzuki¹, Mizuki Sato¹, A. I. M. Hanafi², Yusuke Itoi¹,  
Shigekazu Suzuki¹, Atsushi Ito¹  
¹ National Institute of Technology, Fukushima College, Japan,  
² Institut Universitaire de Technologie de Brois, France

**OT-3 Operating Characteristic of Matrix Converter for Linear Induction Motor**  
Aiko Kubota, Satoshi Ueno, Kouichi Tomiyoshi, Toshimitsu Morizane,  
Hideki Omori, Noriyuki Kimura  
Osaka Institute of Technology, Japan
Oral 5B: Materials
Time: Sep. 8th: 15:30-16:45
Location: Room 2
Chair: Prof. C. B. Part (K. N. U. T.)
Chair: Dr. Y. Shindo (Kawasaki Heavy Ind.)

MT-1 Basic Study on Linear Actuator Using Superconducting Coil
Mochimitsu Komori, Haruka Sagara, Ken-ichi Asami, Nobuo Sakai
Department of Applied Science for Integrated System Engineering, Kyushu Institute of Technology, Japan

MT-2 Experimental Study on Iron Loss Properties of an Amorphous Ring under Different Inverter Excitations
Atsushi Yao, Kouhei Tsukada, Keisuke Fujisaki
Department of Advanced Science and Technology, Toyota Technological Institute, Japan

MT-3 3-D Magnetic Field Analysis Taking Account of Anisotropic Magnetic Hysteresis Property of Electrical Steel Sheet
Shunya Odawara¹, Keisuke Fujisaki¹, Michihiro Nakagawa², Nobuki Kitano², Yoshinari Asano²
¹Kitami Institute of Technology, Japan,
²Technology Research Association of Magnetic Materials for High-Efficiency Motors (MagHEM), Japan
**Poster Session**

Time: Sep. 7th: 14:00 - 15:40  
Location: Room P  
Chair: Prof. J. Asama (Shizuoka U.)  
Chair: Prof. H. Suzuki (National Inst. Tech. Fukushima College)  
Chair: Prof. J. Kluehspeis (Int. Maglev. B.)  
Chair: Prof. C. B. Lee (Korean National University of Transportation)

**P-01**  **Thrust Ripple Reduction Method of Inner Magnet Linear Synchronous Motor**  
Haruka Hirano, Shunji Tahara, Kokichi Ogawa  
Department of Architecture and Mechatronics, Oita University, Japan

**P-02**  **Design Parameter Analysis of the Linear Induction Motor for Maglev Conveying System**  
Wooyoung Ji¹, Geochul Jeong², Juntae Kim³, Ju Lee², Hyung-Woo Lee¹  
¹Department of Railway Vehicle System Engineering, Korea National University of Transportation, Korea,  
²Department of Electrical Engineering, Hanyang University, Korea,  
³Department of Computer Science and Engineering, Dongguk University, Korea

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Tadashi Hirayama, Shuma Kawabata
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