



Akira Chiba (S'82- M'88- SM'97- F'07) is currently a Professor in the Department of Electrical & Electronic Engineering at the Graduate School of Science and Engineering of the Tokyo Institute of Technology. He received BS, MS, and PhD degrees in Electrical Engineering from the Tokyo Institute of Technology, in 1983, 1985 and 1988, respectively.

In 1988, he became a Research Associate in the Department of Electrical Engineering in the Faculty of Science and Technology at the Tokyo University of Science. There, he served successively as a Research Lecturer from 1992 to 1993, Senior Lecturer from 1993 to 1997, Associate Professor from 1997 to 2004, and Professor from 2004 to 2010. In 2010, he joined the faculty of the Tokyo Institute of Technology, where he has been Professor ever since. During his years as Research Associate, in 1990-91, he was awarded an NSERC (Natural Science and Engineering Research Council of Canada) International Post-Doctoral Fellowship at Memorial University in Newfoundland, Canada.

Dr. Chiba has been studying magnetically suspended bearingless ac motors, and rare-earth-free-motors for hybrid and pure electrical vehicles. In 1988, he proposed the basic concept of bearingless motors having additional stator windings, field-oriented controllers and inverters for non-contact magnetic suspensions. The basic concept suggested the possibility of converting most electric motors into bearingless motors. He has been developing a variety of bearingless motors with principles of induction, SPM, IPM, buried PM, inset PM and other types of motors to verify the concept. In these investigations, he has found that consequent-pole PM and homopolar motors have superior characteristics as bearingless motors. He has been also studying wide gap bearingless motors without additional suspension windings, but with novel winding structures.

He presented his concept of rare-earth-free motors at a keynote lecture of the 2011 IEEE International Electric Machines and Drives Conference in Niagara Falls. Rare-earth-free motors are post-rare-earth PM motors not including NdFeB permanent magnets. The NdFeB PM motors are widely used in hybrid and pure electrical vehicles. The limited supply and the increased cost of NdFeB permanent magnets are one of main concerns for further mass production of environmentally friendly vehicles. Without rare-earth NdFeB PMs, it is said that performance values such as motor torque, power and efficiency are generally inferior; however, the concept of a rare-earth-free motor is a compelling one. Rare-earth-free motors must have competitive efficiency, shaft output power, and outer dimensions similar to those of the rare-earth PM motor. He has been developing several switched reluctance motors without rare-earth PMs that are competitive with rare-earth PM motors from the point of view not only of efficiency and shaft output power, but also torque density and operating speed-torque area. The target rare-earth PM motor application is for hybrid electric vehicles.

He has so far published more than 884 papers including his first book, *Magnetic bearings and Bearingless Drives*, in 2005, and has submitted 60 patents. He received the IEEJ Paper Awards in 1998 and 2005. He received the First Prize Paper Award on a switched reluctance motor development from the Electrical Machine Committee in the IEEE IAS in 2011. He has been a member and Chair of the IEEE Nikola Tesla Award Committee in 2010-2012 and 2013-present, respectively. He has been served as Secretary, vice-Chair, vice-Chair-Chair-elect, and Chair of the Motor Sub-Committee of the Electric Machinery Committee in the IEEE PES in 2007-2008, 2009-2010, 2011-2012, and 2013-present, respectively. He served as vice-Chair and Chair of the IEEE IAS Japan Chapter in 2008-2009 and 2010-2011, respectively. He has been a member of the Electric Machine Committee and the Industrial Drives Committee in IEEE IAS. He has been an IEEE Fellow since 2007 for his contributions to bearingless AC motor drives.

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Proposed Lecture Topics

I. Magnetically Suspended Bearingless Motor

1. Basic idea and motivation
2. Force distribution in a motor
3. Some developments for specific applications
4. Consequent-pole bearingless motor, controller and power electronics
5. Outer rotor and multi-pole structures, sensors and etc.

Magnetic bearings and a motor are widely installed in a shaft in compressors, chemical pumps, turbo-molecular pumps, blood pumps, etc. In these applications, the motor and magnetic bearings are constructed in the shaft in tandem. The motor and magnetic bearings generate rotating torque and suspension radial forces, respectively. In motors, it is well known that radial force is generated when flux distribution is unsymmetrical. A bearingless motor intentionally makes its flux distribution unsymmetrical and generates radial force for magnetic suspension. The bearingless motor is a magnetically combined electric motor with a magnetic bearing. At the beginning of this lecture, the basic idea and motivation of bearingless motor developments are presented. The integration of magnetic bearings and the motor enhance force and torque capability, or shorten the total shaft length. Then, flux distributions in the PM motor are presented to show the magnetic stress force along the rotor surface. It is shown that there are tangential stress forces for torque generation, but also a significant radial stress force acting in the radial direction, although the integration of the radial stress forces is zero if the flux distribution is symmetrical. A simple winding method to make flux distribution unsymmetrical is provided, and radial force is introduced to demonstrate the advantages of a magnetically combined bearingless motor.

Some bearingless motor developments for specific applications are presented to illustrate industrial applications. Several development examples are presented such as consequent-pole bearingless motor for pump applications, controller and power electronics developments, an outer rotor and multi-pole structures, integrated position sensors, and etc.

II. Developments of Rare-Earth-Free-Motor for Hybrid Electric Vehicles

1. Rare earth problem in electrical motors
2. Performance of NdFeB PM motors for hybrid electrical vehicles.
3. Overview and some developments of rare-earth-free motors.
4. Switched reluctance motor design
5. Test results and comparison to NdFeB IPMSM.

In order to reduce CO₂ emissions and prevent global warming, hybrid and pure electrical vehicles have been introduced in automobiles. The number of these environmentally friendly vehicles has been significantly increased recently. These vehicles have a motor to assist an internal combustion engine to enhance the fuel efficiency. Most motors include rare-earth permanent magnets, i.e., NdFeB permanent magnets. However, NdFeB permanent magnets require rare-earth materials, namely neodymium (Nd) or dysprosium (Dy). The Dy is needed to enhance the high-temperature characteristics; those are required in hybrid electrical vehicles because the motor is installed in the engine room. The problem with rare earth materials is their limited supply and high cost. For Nd and Dy, the material costs peaked in July 2011, then decreased; however, the costs in 2012 are still 20 and 31 times those in 2006, respectively.

In the lecture, the rare-earth problem for motor production is presented. Then, the performance of hybrid electrical vehicles is presented in assessing the current status of NdFeB PM motors. An overview and some developments in rare-earth-free motors are reviewed. One example of switched reluctance motor development is presented in detail. It is shown there are three keys to enhancing the torque density, efficiency and operating range to be competitive with NdFeB motors employed in hybrid vehicles. In addition to the design process, test machine developments and test results are presented.