AP4-1-INV

Large Rotating Machines using HTS

*Tabea Arndt[1]

Siemens AG[1]

The unique capability of superconductors to carry very high currents in small cross sections even at considerable magnetic fields has attracted engineers of rotating machines very early – even before the discovery of the high-temperature superconducting materials (HTS). There have been built motors and generators based on LTS-wires cooled by cryogenic Helium in the 70's of the last century.

The HTS avoiding the high cooling penalty of the low temperature operation of LTS opened up new opportunities for mid-power rotating machines. At the same time, the importance and share of synchronous machines increased and new fields for application became significant, e.g. wind power.

We will discuss the basic challenges and opportunities of different rotating machines for electric aircrafts, power generation and propulsion, and how aspects of material and machine will interplay.

Keywords: rotating machines, HTS, Propulsion, Power Generation

AP4-2-INV

Application of HTS for ship propulsion motor

*Mitsuru Izumi[1]

Tokyo University of Marine Science and Technology (TUMSAT)[1]

Superconducting rotating machines continue to attract technical and scientific interest and assessment, with progressive research and development ongoing in both academia and industry since the discovery of high-temperature superconductors. High power density and efficiency, even with possible compromise on cost would be a goal for ship propulsion motors. In the beginning, we illustrate the evolution of electric propulsion motors, and report the status of R&D of HTS motors in TUMSAT.
High-temperature superconducting (HTS) materials offer a mature technology for propulsion motor/generators in transportation. In Japan, 1-3 MW synchronous motors for ship propulsion have been developed by industry-national institute-academia liaison using HTS wires. As an alternative technology for the field poles, melt-growth bulk HTS materials have provided the basis of a successful design and prototype demonstration of modules for 10-30 kW proof-of-concept rotating machines. An effective magnetization technique for a high magnetic flux density of the HTS bulks is a key which potentially offers a superior field pole flux and torque density compared with conventional PM machines.
In large output power applications, such as wind/ocean renewable energy generators and ship/aeronautic propulsion motors, these machines are highly desirable because of their potential for a high energy density per weight and volume. In this paper, we report the current status of works concerning activity of the TUMSAT group and others towards the development of superconducting ship propulsion motors.

[1] Kiruba S. Haran et al., High power density superconducting rotating machines – Development status and technology roadmap, *Supercond. Sci. and Tech.*, http://iopscience.iop.org/article/10.1088/1361-6668/aa833e.
[2] Toshiyuki Yanamoto, Mitsuru Izumi, Minoru Yokoyama, Katsuya Umemoto, *Proceedings of the IEEE*, 103, No. 12, pp. 2333-2343 (2015).
[3] Miki et al., Novel Design of a 30 kVA Rotor System with Bulk High Temperature Superconductor for a Motor/Generator, Abstract and presented in Applied Superconductivity Conference, ASC2014, Charlotte, NC and M Izumi and M Miki, *Radial-gap-type superconducting synchronous machine, magnetization device, and magnetization method*, EP 3125415 A1, Feb. 2017, PCT/JP2015/059155.

Keywords: HTS synchronous motor, Ship propulsion motor

AP4-3-INV

Current Status of Superconducting motor for Aviation Application

*Vladimir T. Penkin[1]

Moscow Aviation Institute (National Research University), Russia[1]

Sustainable development in the direction of electric aircraft, more electric aircraft (MEA) and fully electric aircraft (FEA) in order to diminish or completely exclude onboard hydraulic and pneumatic systems opens an opportunity to use superconducting electric drives in the frame of that conception. Two trends of their application are under consideration. The first is a drive of propeller or fan and relates electric machines of MW class with power supply according to scheme "turbine → superconducting alternator" or fuel cells. The second trend is the use of superconducting electric drives of kW class in onboard systems. Different types of synchronous superconducting electric drives are considered which can be developed with the use of modern superconducting materials: wires, tapes, bulk elements, foliate composites or their stacks. The peculiarities of development are given for synchronous superconducting electric hysteresis and reluctance motors as well as motors with permanent magnets and bulk materials in the rotor. The results of experimental comparison of output performances of reluctance motors with different superconducting materials in the rotor at temperatures 77K and 15…20K are presented. The project of business class aircraft with hydrogen fuel and electric drive of propeller is described.

Keywords: aircraft propulsion, electric motor, superconducting material, permanent magnet

AP4-4-INV

Development Status of 50 kW Class Fully Superconducting Induction/synchronous Motor for Transportation Equipment

*Taketsune Nakamura[1], Ryohei Nishino[1], Tetsuji Matsuo[1], Masaaki Yoshikawa[2], Yoshitaka Itoh[2], Toshihisa Terazawa[2], Yoshimasa Ohashi[3], Satoshi Fukui[4], Mitsuho Furuse[5]

Kyoto University, Japan[1]
IMRA MATERIAL R&D Co., Ltd, Japan[2]
AISIN SEIKI, Co., Ltd[3]
Niigata University, Japan[4]
AIST, Japan[5]

This paper presents development status of a 50 kW class fully superconducting induction/synchronous motor for next generation transportation equipment, e.g., train, bus, electric vehicle. We have proposed and developed so-called ring-windings for the superconducting stator, which could improve the critical current of such windings in iron core. 3-ply BSCCO superconducting conductor is utilized for the racetrack structured double pancake coils, and 4-pole stator windings have been successfully developed. DC and AC current transport property is reported. Furthermore, rotation test results of a fabricated fully superconducting motor, which adopt the above stator, is also presented and discussed.

This work has been supported by Japan Science and Technology Agency under the program of Advanced Low Carbon Technology Research and Development Program (JST-ALCA).

Keywords: Superconducting Motor, Induction/synchronous Motor, Transportation Equipment, Superconducting Stator