Tutorial on

Material Tradeoff for Sustainable Electrical Machines in Demanding Applications

Tutorial Presenters

- **Ahmed Selema**, Drive13 BV, Belgium, selema@drive13.tech
- **Nick Simpson**, University of Bristol, UK, Nick.Simpson@bristol.ac.uk
- **Ayman EL-Refaie,** Marquette University, USA, ayman.el-refaie@marquette.edu

Biographies of the Presenters

Ahmed Selema is an industry-oriented innovator in smart and sustainable manufacturing technologies, driving innovation in the future electric motors. With over 10 years of experience in the field and a PhD from Ghent University (Belgium), he combines deep technical expertise with a strong entrepreneurial mindset. As an industrial research engineer, he has worked closely with leading international industrial partners on cutting-edge R&D projects. He currently works as CTO & technology director of Drive13, where he leads the company's product development and innovation strategy. As a technology-driven enthusiast, he focuses on transforming pioneering ideas into scalable, real-world solutions. With a strong background in advanced manufacturing and hands-on engineering, he has been at the forefront of developing next-generation solutions for electrical machines known for their market-leading power density, efficiency, and sustainability.

Nick Simpson received the B.Eng. and Ph.D. degrees in electrical engineering from the University of Bristol, Bristol, U.K., in 2009 and 2014, respectively. He is currently an Associate Professor and the Head of the Electrical Energy Management Group, Department of Electrical and Electronic Engineering, University of Bristol, Bristol, U.K. His research focuses on performance improvement of electrical machines through advanced multiphysics design and manufacturing techniques, with a particular interest in additive manufacturing of active components.

Ayman EL-Refaie received the M.S. and Ph.D. degrees in electrical engineering from the University of Wisconsin Madison in 2002, and 2005 respectively. Between 2005 and 2016 he has been a principal engineer and a project leader at the Electrical Machines and Drives Lab at General Electric Global Research Center. His interests include electrical machines and drives. Since January 2017 he joined Marquette University as the Werner Endowed Chair for Energy Sustainability. He has over 250 journal and conference publications. He has 50 issued US patents. He is a fellow of the IEEE, IET and National Academy of Inventors. At GE, he worked on several projects that involve the development of advanced electrical machines for various applications including, aerospace, traction, wind, and water desalination. He was the chair for the IEEE IAS Transportation Systems committee and an associate editor for the Electric Machines committee. He was a technical program chair for the IEEE 2011 Energy Conversion Conference and Exposition (ECCE). He was the general chair for ECCE 2014 and 2015 ECCE steering committee chair. He was the general chair of IEMDC 2019. He was the IEEE IAS Industrial Power Conversion Systems Department. He was the IAS Publications Department Chair He is currently serving as the IAS president. He is a member of Sigma Xi. He received several prestigious awards including the IEEE IAS Industrial Power Conversion Systems Department Gerald Kliman Innovator Award, the 2022 ICEM Arthur Ellison Achievement Award, the 2024 IEEE Power & Energy Society (PES) Cyril Veinott Electromechanical Energy Conversion Award, and the 2024 IEEE PELS Electrical Machines, Drives and Related Automation Technical Achievement Award among several others. He is the recipient of five paper awards.

Abstract

Applications of traction, aerospace, and high-performance industrial drives face intertwined constraints: efficiency targets, mass/volume limits, harsh thermal cycles, cost and many sustainability requirements. This tutorial presents a data-driven framework to align material choice with performance, cost, and environmental impact for sustainable electrical machines.

We compare soft-magnetic electrical steels— e.g. FeCo, NO, GO laminations— covering B–H behavior, loss, frequency scaling, mechanical strength, and manufacturability (stacking, bonding, cutting). For hard magnets, we contrast ferrite, Nd-Fe-B, and Sm-Co with emphasis on remanence/coercivity, temperature coefficients, corrosion and demagnetization margins, and supply-chain criticality. Winding technologies are benchmarked—copper round/Litz, hairpin, hollow conductors, and aluminum alternatives—addressing conductivity vs. density, thermal pathways, joining, coatings/insulation, and recyclability. We connect materials to system-level outcomes: torque density, efficiency, thermal performance, and reliability.

Sustainability is embedded throughout via life-cycle assessment, embodied energy/CO_2, repairability, circularity, and critical materials footprints, with clear reporting templates to satisfy emerging standards. Case studies illustrate trade-off navigation: (i) Nd-Fe-B versus Sm-Co for high-temperature operation; (ii) copper hairpin versus aluminum conductors; (iii) Advanced cooling for high-speed drives.

Finally, the tutorial will highlight advanced case studies of electrical machines for racing and aerospace applications enabled by advanced manufacturing technologies such as 3D printing. This session seeks to bring together latest research findings, theoretical advancements, and practical insights about electrical machine design and manufacturing.

Further validation includes automatic generation and simulation of the electric drive

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