Electromagnetic Simulation: A Catalyst for Innovations in Engineering Education and Research

Abstract

In today's technology-driven era, engineering plays a vital role in our daily lives. With rapid advancements in fields such as transportation, communication, and energy, engineers are constantly challenged to innovate and create new technologies. A solid understanding of electromagnetic simulation is crucial to meet these challenges effectively.

This application note delves into the significant impact of electromagnetic simulation on engineering education and research. We will explore the advantages of simulation, including its ability to enhance design processes and provide deeper insights into complex systems.

Introduction

Electromagnetic Simulation relies on mathematical models to forecast and replicate the behavior of electromagnetic systems. This technology holds immense significance in fields like electrical engineering, physics, and telecommunications. It empowers the optimization of various devices, including electric motors, communication systems, and antennas.

The evolution of computational methods for electromagnetic simulation commenced in the 1960s, driven by advancements in numerical techniques and computer hardware. Today, this evolution persists, with the ongoing development of innovative methods and software aimed at addressing increasingly intricate problems. Electromagnetic simulation serves as a valuable asset for scientists and engineers, enabling them to make precise predictions regarding electromagnetic fields and waves.
Its applications span a wide spectrum and continue to gain importance in tandem with the continuous progress of technology and the emergence of new challenges.

Fig. 1. Double Twin-Screw Coil [1]	Fig. 2. Simulation Results: Open Coil Design [1]	Fig. 3. Axial Flux YASA Type Motor [2]	Fig. 4. Simulation Results: Full Saturation B [T] [2]

Applications

Electromagnetic simulation finds diverse applications across numerous industries, demonstrating its versatility and significance. These applications include:

1. Transformers and Power Engineering: Particularly in high-power and high-voltage applications, where accurate simulation is vital.

2. Multiphysics: Applied to electro-thermal, magneto-structural, and electro-structural systems, enabling comprehensive analysis.

3. RF and Microwave Components: Simulation aids in the design and optimization of filters, connectors, and transmission lines for efficient communication systems.

4. Electronic Design Automation: Beneficial for chip package board systems, capacitors, and printed circuit boards, ensuring optimal electronic designs.

5. Magnets and Magnet Arrays: Used in the simulation of magnetic levitation vehicles, magnetic gears, and permanent magnets for various applications.

6. Actuators, Solenoids, and Electromechanical Devices: Models are created for linear and rotational actuators, solenoids, and MEMS devices to enhance their performance.

7. Sensors and Non-Destructive Testing/Evaluation: Simulation technology is applied in sensor development and non-destructive evaluation methods.

8. Antennas: Utilized in the design and analysis of waveguide and wire antennas for effective signal transmission.

9. Electrical Machines and Drives: Particularly relevant for motors and generators, ensuring their efficiency and performance.

10. Biomedical Applications: Includes simulations related to electromagnetic exposure and the development of medical devices.

11. Electric Vehicle Battery Charging: This plays a significant role in the efficient charging of electric vehicle batteries.

The wide-ranging applications of electromagnetic simulation underscore its importance and adaptability in addressing complex challenges across multiple industries.

Fig. 5. Axial Flux Motor Assembly [3]	Fig. 6. Magnetic Flux Density Fringe Plot [3]	Fig. 7. Assembled Axial Flux Motor [3]	Fig. 8. Assembly of the Coils [3]

Advantages

EMWorks, a prominent supplier of electromagnetic simulation software, presents a series of compelling case studies spanning diverse engineering domains, illustrating the advantages of electromagnetic simulation.

One notable case study hails from the realm of transportation engineering, shining a spotlight on the transformative potential of electromagnetic simulation. The Cal Poly Hyperloop team, a student club committed to advancing high-speed transportation technology at California Polytechnic State University, embarked on the development of a magnetic levitation system for their pod, destined for SpaceX's Annual Hyperloop Pod Competition. Leveraging EMWorks simulation software, the team meticulously analyzed the system's behavior and fine-tuned its performance, all prior to constructing a physical prototype. This strategic employment of simulation not only conserved valuable time but also yielded cost savings—a testament to the efficiency and efficacy of electromagnetic simulation in real-world engineering challenges.

Fig. 14. CAD Model of Magnetic Levitation Wheel [5]	Fig. 15. Machined Wheel with Installed Magnets [5]	Fig. 16. Side View of the Wheel Containing the Magnet Array [5]	Fig. 17. Eddy Currents Formed when the Wheel Spins over the Sub-Track [5]

Another case study is from the aerospace engineering field, where the University of Illinois used EMWorks' electromagnetic simulation software to design and verify a high-performance resistor for an ohmic-heated hypersonic wind tunnel. Through electromagnetic simulation, they improved the resistor's performance in terms of temperature uniformity and heating time, saving time and resources.

Fig. 18. Design Prototype [6]	Fig. 19. Schematic of an Ohmic-Heater for a High-Enthalpy Hypersonic Wind Tunnel [6]

Fig. 20. Temperature Profiles of Various Designs [6]

In the field of bioengineering, the College of Tropical Agriculture and Human Resources designed and optimized a solenoid for magnetic field treatment using finite element analysis. The students used EMWorks' electromagnetic simulation software to identify the optimal design for the solenoid and secured first place in the Poster category at the 2018 Student Research Symposium.

Fig. 21. Solenoid Mesh with Arrows Indicating Electrical Current Direction [7]	Fig. 22. Side View of Flux Vectors [7]

Fig. 23. Top View of the Steady State Temperature in the Solenoid [7]	Fig. 24. Temperature vs Time of the Actual Device [7]

Fig. 25. Award at Student Research Symposium [7]

Now, in the field of mechanical engineering, the Department of Mechanical Engineering at Rajiv Gandhi Institute of Technology used electromagnetic simulation to analyze and design active magnetic bearings. The project aimed to improve and implement this technology, which has a wide range of applications in various industries, including aerospace, power generation, and transportation.

Fig. 26. CAD Model of the Active Magnetic Bearing [8]	Fig. 27. Generated Mesh [8]	Fig. 28. Contour Result of Magnetic Flux for Single Pole Actuation [8]	Fig. 29. Contour Result of Magnetic Flux for Complete Actuation [8]

Testimonials

Testimonials from students and researchers hailing from various universities serve as compelling endorsements of the effectiveness of EMWorks' electromagnetic simulation software.
A Ph.D. candidate at the University of Calgary expressed heartfelt appreciation for the software donation, emphasizing its pivotal role in refining their motor design. The student lauded the software's user-friendly interface and commended the accuracy of the results it produced. Similarly, a student from the South Dakota School of Mines and Technology shared a positive account of their experience with EMWorks software while designing a brushless motor prototype. The student found the software to be intuitive and underscored the valuable support provided by the EMWorks team throughout their endeavor.
These testimonials underscore the indispensable role of electromagnetic simulation in engineering education and research, showcasing how EMWorks' software contributes to the success of students and researchers in these domains.

Conclusion

EMWorks extends accessible academic licenses for their electromagnetic and thermal simulation software, extending invaluable advantages to students and researchers in the academic realm. These affordable licenses not only enrich learning experiences but also equip students with essential skills for their future pursuits in engineering and science.
EMWorks further demonstrates its commitment to academia by offering comprehensive training, dedicated support, and a repository of real-world examples. These resources are designed to empower educators, students, and researchers alike, fostering an environment of innovation and experimentation within academic institutions.
In addition, EMWorks actively collaborates with universities and research centers across the globe, thereby contributing to the advancement of academic research in the fields of electromagnetics and thermal analysis. This collaborative spirit underscores EMWorks' dedication to supporting and elevating academic pursuits in these domains.

References

[1] Whitepaper: University of Žilina, Slovakia - Design of an open coil for inductive preheating of wires in production line
[2] Whitepaper: School of Mining, Energy and Manufacturing Saskatchewan Polytechnic - Design and analysis of YASA type motor
[3] Whitepaper: Military University of New Granada - Axial Flux electric motor
[4] Whitepaper: Imperial College London - Magnetic Field Enhancement of the Quad Confinement Thruster
[5] Whitepaper: California Polytechnic State University - Cal Poly Hyperloop Magnetic Levitation Analysis using EMWorks Simulation Software (EMS)
[6] Whitepaper: University of Illinois at Urbana-Champaign - Design of a resistor for an ohmic-heated hypersonic wind tunnel
[7] Whitepaper: University of Hawaii - Design and Optimization of a Solenoid for Magnetic Field Treatment Using Finite Element Analysis
[8] Whitepaper: Rajiv Gandhi Institute of Technology - Analysis of Active Magnetic Bearings