

# Computational Electromagnetics: the Achievements, the Challenges and the Future

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**Abstract:** The paper provides an overview of the state of the art in Computational Electromagnetics. Design and optimisation, as well as developments in new materials, are emphasised. Modern methods such as finite elements have become a mature design tool, but the complexity of the underlying mathematics and physics often hampers widespread use of these techniques. Recent advances in general purpose software are encouraging but much remains to be done in improving the standards of education to remove the mist of mystery surrounding the subject.

**Keywords:** computational electromagnetics, finite elements, optimisation, CAD in magnetics.

## I. INTRODUCTION

The research activity known as Computational Electromagnetics (CEM) has evolved alongside the modern developments in the digital computing hardware. Moreover, CEM is both a special case and part of the broader subject of computational mechanics. The speciality arises in many obvious ways, e.g. free space is an unbounded magnetic ‘material’, there is a vast range of physical dimensions encountered with critical feature sizes often varying over many orders of magnitude, the fundamental properties of Maxwell’s equations are different to equations governing other physical phenomena. There is also a very broad spectrum of frequencies encountered: from DC to daylight. Activities of the CEM community are well organised within the International Compumag Society [1], an independent international organisation in existence since 1993 with nearly 700 members from over 40 countries. The IEE Professional Network on Electromagnetics [2] is also gaining momentum and establishing itself as an international forum for discussion. The IEEE Magnetics Society [3] and ACES [4] manage the activities in North America. Journals such as IEE Proceedings [5], IEEE Transactions on Magnetics [6] and COMPEL [7] contain a significant number of papers showing fundamental advances and applications of CEM. There are many conferences reporting regularly on recent developments, including COMPUMAG, CEFC, CEM, ISEF, EPNC, ISTET, ISEM and of course the IGTE symposium.

## II. STATE OF THE ART

There has been important progress in fundamental formulations providing more solid foundations for numerical field analysis. Lack of space does not permit to elaborate on these developments here but some more exciting advances include: higher order Finite Difference Time Domain approach, further developments of the Transmission Line Matrix method, advances of the Multiple Multipole Technique, the use of Finite

Integration Technique, a Subspace Projection Extrapolation scheme, development of new types of materials (see Figure 1), formulations in terms of differential geometry, implementation of edge and facet elements, improved anisotropy models, efficient application of Continuum Design Sensitivity Analysis and many other.

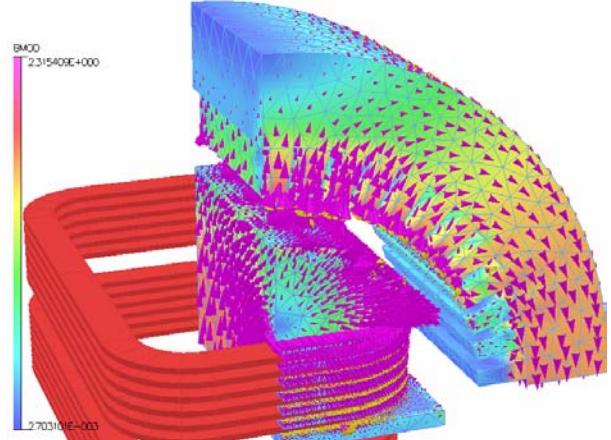


Figure 1: Magnetic field in a superconducting generator.

## III. FUTURE DEVELOPMENTS

Further progress is required and a possible list of topics for research and development may include:

- adaptive meshing with particular emphasis on problems with strong skin effect and anisotropy,
- reliable error estimation (a posteriori and a priori),
- code development for high speed computing,
- efficient modelling of non-linearity and hysteresis,
- new type of materials (composite, superconducting),
- linear movement and rotation of parts of the device,
- combined modelling of fields and circuits,
- coupling (electromagnetic + stress + temperature, etc),
- optimisation (deterministic, stochastic, multiobjective),
- integrated design systems (combined mechanical, electromagnetic, thermal, economic).

It can be argued, however, that CAD in Magnetics is already a mature tool for design and optimisation of a variety of electromechanical devices and the engineering community can benefit from tremendous advances that occurred in the field over the past many years.

## REFERENCES

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