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The Role of Finite Elements in the design of Particle Accelerators & Medical Science

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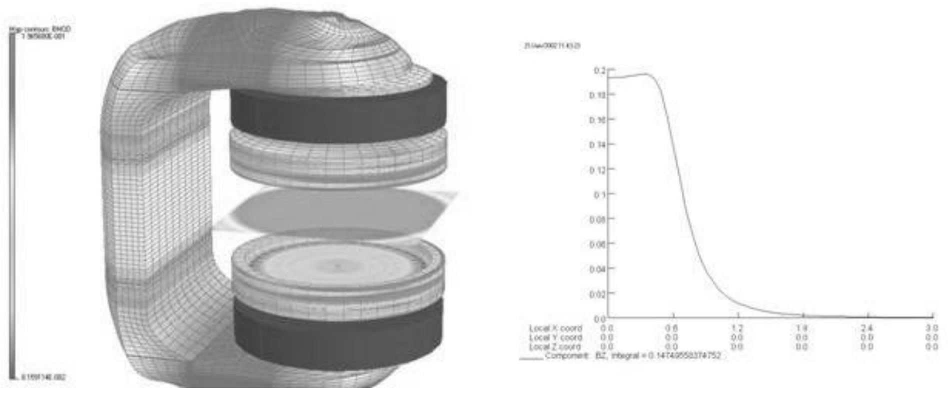
ABSTRACT

The Finite Element Method has played a very important role in the design of the sophisticated equipment used in High Energy Physics experiments including particle accelerators, particle event detecting devices such as Bubble Chambers, Counters etc. as well as in the experiments that one day may lead to an alternative method of energy production with a very low carbon foot print by using nuclear fusion. The method has also made a very significant impact in the design of equipment used in medical science such as diagnostic scanning which included MRI (Magnetic Resonance Imaging). All of these applications have one critical component in common and that is they all use electromagnets. Two examples from the medical science are shown in Figures 1 & 2.

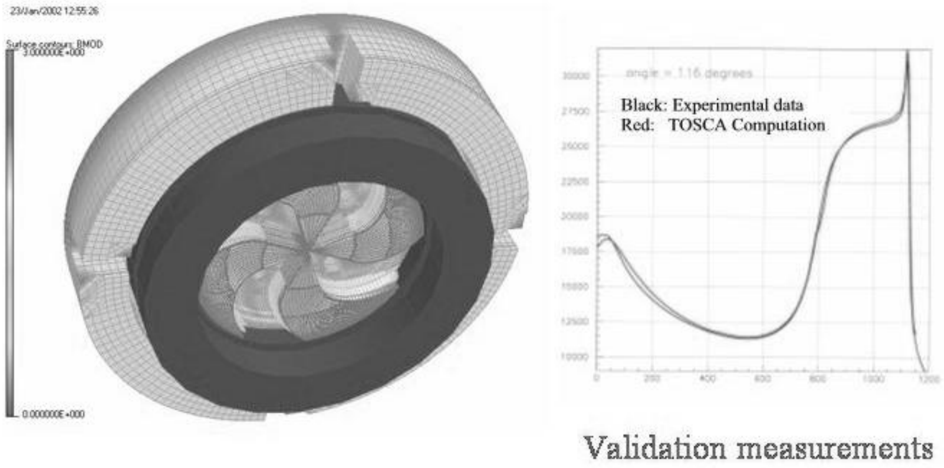


(c) Field Solution Contours of Flux Density

(d) Fringe Field (Tesla)

Figure 1: *Open MRI System from Oxford Magnet Technology [1]*

Figure 1 shows the model and field solutions of an open MRI (Magnetic Resonance Imaging) main magnet designed and built by Oxford Magnet Technology in Oxford, UK [1]. Figure 2 shows the model and solution for the 235 MeV proton therapy cyclotron designed and built by IBA in Louvain [2]. In Figure 2(b) a comparison of the field solution is shown against measurements with close agreement. The modelling and field solution was carried out using Vector Fields OPERA system [3].



(a) Computer Model (b) Comparison of Field predictions with measurements

Fig. 2: *335 MeV Cyclotron for Proton Therapy designed by Ion Beam Applications Louvain, Belgium[2]*

Computational Electromagnetics (CEM) is both a special case and part of the broader subject of computational mechanics. This speciality has been discussed in a previous papere [4]. The speciality arises in many obvious ways, e.g. free space is, in general, an unbounded magnetic material and any modelling, often involving complex structures, has to take this into account, see Fig. 1. Also for problems involving high frequency, where waves are propagated, the choice of mesh size in the discretised space with respect to wavelength becomes critical. Furthermore the large range of dimensions often encountered in CEM can lead to difficulties. The speciality also arises more subtly as Maxwell's equations in general have fundamental properties that are different say from the Navier-Stokes equations, which govern fluid mechanics. On the other hand CEM's debt to mechanics and applied mathematics is profound and much of what is done in CEM is very similar to continuum analysis in other disciplines, e.g. thermal, structural and fluids. The presentation will outline the main achievements in the use of FE in CEM and will discuss some important limitations which need new research to address.

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