A Study on Uniformity of a Magnet

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Introduction: Penning ion trap is a device used for three-dimensional confinement of ions for high precision nuclear and atomic physics studies. In a Penning ion trap, superposition of a strong homogeneous magnetic field and a weak quadruple electric field confines the ions in a very small region. An electromagnet has been fabricated in VECC for a room temperature Penning ion trap. A COMSOL multiphysics simulation has been attempted to compute the magnetic field which is in reasonable agreement with measured values. Simulations studies for the heat transfer to the circulating water is in progress.

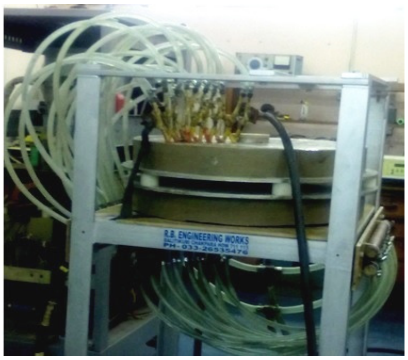

Figure 1. Electromagnet at VECC

Parameter used:

Name	Expression	Value	Description
J0	8040844.536679 21163295012755	8040845	Current Density in each coil

Table 1.

Geometry Parameters used:

Inner Diameter	90 mm
Outer Diameter	506 mm
Gap height between the coils	40 mm
Number of turns (nr × nz)/coil	32 × 7
Conductor size (without insulation)	6 mm×6 mm
Hole diameter	2.5 mm

Table 2.

Computational Methods: The magnet consists of two pancakes arranged vertically with a separation of 3cm with a central bore as shown in Figure 1. Each pancake consists of 32 helical coils and each helix has 7 turns. The coil carrying current is a hollow copper conductor having square cross-section. Low Conductivity Water (LCW) is circulated through the central bore of copper conductor for cooling. The spiral coil is casted in an epoxy for rigidity.

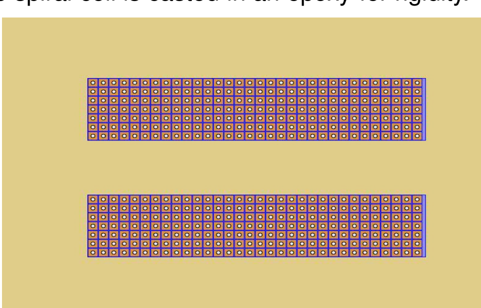

Figure 2. Geometry of the Magnet

Simulation study has been performed using COMSOL Multiphysics considering a 2D axi-symmetric model. Thus each pancake has been represented by 32×7 squares constructed at their respective positions each having a hole in them. A rectangle is created outside which borders the 32 blocks for filling in the insulation. A copy of this rectangular block is made and placed at a position symmetric with respect to the z=0 axis. The size of the meshing depends on the geometry parameters.

Results: Magnetic field at the central point between two pancakes was determined using standard procedure. First we studied the effect of domain boundary dimension on magnetic field calculated. An optimal dimension of 1m X 1m was considered and magnetic field was calculated varying current density parameter. Figure 3 shows the variation of the magnetic field with radial distance. Figure 4 shows a comparison of the simulated magnetic field and the experimental data. Figure 5 shows the change of the magnetic flux density with the z co-ordinate.

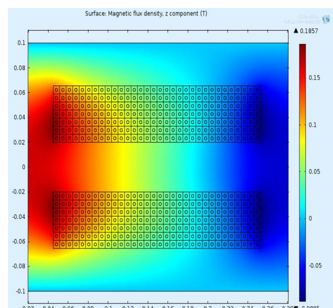

Figure 3.
Magnetic Field Variation

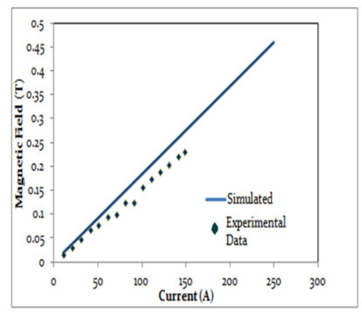

Figure 4.
Field Variation with Current

Figure 5. Magnetic flux density along z axis

Conclusions: The simulation result and experimentally measured values of magnetic field of the magnet studied agrees with a few micro-Teslas. The experimental and the simulated magnetic field strength increases with increasing current and simulation results matches with design value. Along the central line along z-axis we find that there is an uniformity in the magnetic field.

References:

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