Magnetic Field Measurements

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Abstract

This report presents the methodologies and findings of experiments aimed at measuring magnetic fields using Hall sensors and analyzing quadrupole magnet fields with a rotating coil. We validate theoretical models such as the Biot-Savart law and conformal mapping techniques through practical measurements and data analysis.

1 Introduction

Magnetic field measurements are pivotal in accelerator physics to ensure the precision and efficiency of particle trajectories. The Hall sensor is widely used for direct measurements as a result of its high sensitivity and accuracy. Quadrupole magnets, crucial for beam focusing, require precise field characterization to optimize performance. This report integrates theoretical concepts with experimental data to achieve a comprehensive understanding.

2 Experimental Setup and Methods

2.1 Hall Sensor for Magnetic Field Measurement

The Hall sensor was used to measure field strength at various locations. The experimental apparatus included a calibrated Hall sensor, a data acquisition system, and a uniform magnetic field generated by a dipole magnet. Measurements were recorded at equidistant intervals, and the field strength was mapped.

Figure 1: Experimental setup for measuring magnetic fields using a Hall sensor.

2.2 Quadrupole Magnet Field Analysis with Rotating Coil

The field distribution of a quadrupole magnet was analyzed using a rotating coil connected to a precise positional control mechanism. The rotating coil measures variations in the magnetic field across different axes to determine field gradients and multipole components.

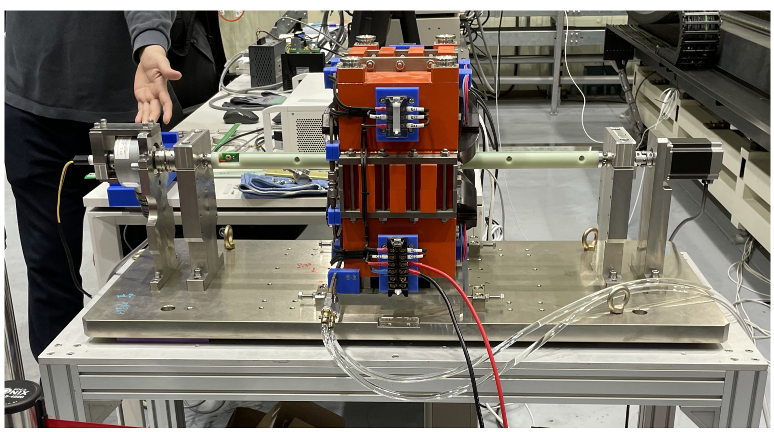

Figure 2: Quadrupole magnet field analysis using a blade probe.

3 Results and Discussion

3.1 Hall Sensor Measurements

The measurements demonstrated a uniform field consistent with theoretical predictions based on the Biot-Savart law. The variations were within the acceptable range of error, indicating the reliability of the Hall sensor for static field measurements.

3.2 Quadrupole Magnet Field Distribution

The rotating coil results revealed the expected quadrupole field pattern. The conformal mapping theory was validated, with skew and normal components analyzed using multipole expansion techniques:

$$B_x = -\frac{\partial V}{\partial x}, \quad B_y = -\frac{\partial V}{\partial y}.$$

The skew components were negligible, confirming the symmetry of the design.

4 Conclusion

The experiments successfully validated the theoretical models used in magnetic field analysis. The Hall sensor provided precise measurements of static fields, while the rotating coil accurately characterized the quadrupole magnet's field distribution. These findings support the ongoing development and optimization of magnetic systems in particle accelerators.

References

1. CERN S. Russenchucks, Lecture Notes on Accelerator Physics.
2. Principles of Cyclic Particle Accelerators, John J. Livingood, 1961.