Magnetic field distribution for 400 MHz all-REBCO magnet after ferromagnetic shimming with sequential search design method

Hongmin Yang1,2, SangGap Lee2, and Minchul Ahn1

1. Department of Electrical Engineering, Kunsan National University, Gunsan, Korea
2. Center for scientific instrumentation, Korea Basic Science Institute, Cheongju, Korea

Background

➢ It is difficult to shim the all-REBCO magnet because of the screening current induced field.
➢ Ferromagnetic shimming is one of very effective methods for all-REBCO magnet.
➢ The design with sequential search is an intuitive method and results can be obtained quickly.

Objectives

➢ Application of a ferromagnetic shimming to all-REBCO magnet.
➢ Ferromagnetic shimming design with sequential search method.
➢ Estimation of the magnetic field distribution for a 20 mm diameter spherical volume (DSV).

Theory

Helical mapping path

• Number of locations : 128
• Diameter : 28 mm
• Height : 30 mm
• Revolution : 6
• dp : 17.0014

An iron piece @ point Q generates a magnetic vector potential at point P

\[ B_z = \mu_0 \frac{\chi \cdot dV}{4\pi} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} \left( \frac{n - m + 1}{n} \right) r_n^m \left( \cos \alpha \right) r_n^{m+1} \left( \cos \beta \right) \cos \left( \phi - \psi \right) \]

Sequential search design method

➢ Theory
• Sequential search method checks each element that makes target value minimum.
  - Excluding one of the n variables, n-1 variables are fixed to improve the approximation point.
  - Continue searching by selecting one of the n-1 variables fixed in the previous iteration.
  - Select all coordinate directions sequentially and search them in n directions.

➢ Flowchart

Design result of the ferromagnetic shimming

Ferromagnetic shim set composed of iron pieces

• Ferromagnetic shim set
  - Diameter : 66 mm
  - Height : 72 mm
  - Number of shim pieces : 146 (maximum 960)

• Shim elements
  - Width : 4.87 mm (azimuthal)
  - Height : 30 mm (axial)
  - Thickness : 10 mil (= 0.254 mm) only
  - Estimated result @ 20 mm DSV : 1.15 ppm

Specification of the design result

Estimation of field distribution @ 20 mm DSV

• The magnetic field was measured with 3-D field mapping experiment and ferromagnetic shimming simulation was performed.
• The ferromagnetic shimming design using sequential search method was developed, and the result capable of improving the field homogeneity 241.06 ppm to 1.15 ppm(@ 20 mm DSV, 0.34 ppm @ 30 mm DSV) was obtained.
• It is necessary to conduct additional research and experiments to confirm the suitability and feasibility of the design method.

Conclusion

400 MHz all-REBCO magnet

• Operating current : 185 A
• Operating temperature : < 20 K (conduction cooling system)
• Inner diameter : 100 mm
• Outer diameter : 146.8 mm
• Height : 510 mm
• Number of DPs : 48
• Inductance : 10.3 H