Iron Magnetic Shielding of the Series-Connected-Hybrid Magnet

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Introduction
The NHMFL presently has three magnet projects using Cable-in-Conduit-Conductor (CICC) underway. The magnet for the NHMFL is specified to provide 36 T with 1 ppm field uniformity and stability over a 10-mm diameter spherical volume (DSV). In addition, a shield to reduce the fringe field is required to facilitate instrumentation and operation. The magnet was originally intended to include a superconducting shield coil using NbTi CICC. A ferromagnetic shield is considered as an alternative to the electromagnetic shield coil.

Iron Shield Description
An octagonal iron shield as shown in Fig. 1 is considered. If the plates are 10 cm thick, the fringe field is reduced to acceptable levels and the change in inhomogeneity of the magnet is < 6 ppm, which will be accommodated in the final resistive magnet design. The impact of ramping the magnets in neighboring cells is reduced 50% (from 11 ppm to 5.5 for the 36 magnet in cell 12 and from 18 ppm to 9 ppm for the 45 T outsert) by having the iron shield.

A superconducting shield would reduce the central field of the magnet by 1.2 T while an iron shield increases the field on-axis slightly. By using an iron shield, the Nb$_3$Sn mail coil can become smaller. The mass of the shield will be ~30 tons and the attractive force between opposite plates will be < 30 kN assuming perfect alignment. Mis-alignment of the shield with respect to the magnet will have minimal impact on inhomogeneity. The support structure both for the coil and the shield will be designed to accommodate forces associated with mis-alignment.

Conclusions
Recently the decision was made to replace the electromagnetic shield by a ferromagnetic one. An octagonal array of steel walls 10 cm thick should cost less than 20% of the superconducting shield. Nonlinear magnetostatic analysis was performed for iron shield to confine SCH fringe field as well as shielding fringe field from neighboring magnets in operation. The results indicate that iron magnetization has little impact on field uniformity and iron shielding is a better option than the original active shielding.

References