

SYMMETRY-BASED SUPPRESSION OF PITCH-INDUCED FIELD ASYMMETRY IN COMPACT HELICAL STRIP COIL PAIRS FOR HOMOGENEOUS MAGNETIC FIELDS

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Abstract

Helmholtz-type coil pairs are a standard means of producing a homogeneous magnetic field, but a coil wound from a single continuous conductor is not exactly axisymmetric: turn-to-turn axial progression, coil ends and current leads break rotational symmetry. In large magnets these errors are often small because the pitch angle is small and the useful field region lies deep inside the winding. In compact pairs wound from radially wide helical strips, where the homogeneous region lies between the two coils, the same effects can become first-order limitations. We present a framework for diagnosing and suppressing these asymmetric field errors. The magnetic field of the complete closed circuit, including ends, connections and leads, is calculated from the Biot–Savart law and expanded in interior spherical harmonics (n, m) about the centre, with $m \neq 0$ terms quantifying departure from axial symmetry. Symmetry analysis gives selection rules for mirror, C2, inversion and translated pair topologies. A mirror-symmetric pair suppresses the uniform transverse (1,1) term but retains the linear transverse gradient (2,1), whereas an ideal inversion-symmetric pair, compatible with a series connection, eliminates all even-degree terms, including (2,1), while retaining a uniform transverse (1,1) component that tilts the field direction without degrading homogeneity. Preliminary filament-model calculations show that for a mirror pair with $p = 0.1a$, where a is the mean coil radius, the relative asymmetric deviation is about 4×10^{-3} at $r = 0.1a$. This deviation is nearly independent of turn number for $N = 4\text{--}10$, scales approximately with the pitch angle $p/(2\pi a)$ for $p/a = 0.05\text{--}0.2$, and changes by only about 5% when the radial position of the return conductor is varied. At $r = 0.1a$, the inversion-symmetric topology reduces the asymmetric deviation by approximately one order of magnitude. A Fourier–Parseval relation is also formulated to compare the helical pair with its azimuthally averaged equivalent, providing a basis for subsequent optimisation of the homogeneous field volume and finite-element validation.