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# Wed-Af-Po.07-02: Efficient calculation of self-magnetic field, self-force, and self-inductance for electromagnetic coils with rectangular cross-section

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For designing high-field electromagnets, the Lorentz force on coils must be computed to ensure a support structure is feasible, and the inductance should be computed to evaluate the stored energy and dynamics. Also, the magnetic field and its variation inside the conductor is of interest for computing stress and strain, and due to superconducting quench limits. For these force, inductance, energy, and internal field calculations, the coils cannot be naively approximated as infinitesimally thin filaments due to divergences when the source and evaluation points coincide, so more computationally demanding calculations are usually required, resolving the finite cross-section of the conductors. Here, we present a new alternative method that enables the internal magnetic field vector, self-force, and self-inductance to be computed rapidly and accurately within a 1D filament model. The method is applicable to coils for which the curve center-line can have general noncircular shape, as long as the conductor width is small compared to the radius of curvature. This work extends our previous calculation for circular-cross-section conductors [Hurwitz et al, IEEE Trans. Magnetics (2024)] to consider the case of rectangular cross-section. The reduced model is derived by rigorous analysis of the singularity, regularizing the filament integrals such that they match the true high-dimensional integrals at high coil aspect ratio. The new filament model exactly recovers analytic results for a circular coil, and is shown to accurately reproduce full finite-cross-section calculations for a non-planar coil of a stellarator magnetic fusion device. Due to the efficiency of the model here, it is well suited for use inside design optimization.

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