

New method to design stellarator coils without the winding surface.

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The inherent advantage of steady-state operation leads to increasing focuses on stellarators. Finding an easy-to-build coil set has been a critical issue for stellarator design for decades. Conventional approaches assume a toroidal 'winding' surface, but a poorly chosen winding surface can unnecessarily constrain the coil optimization algorithms.

We present a new method to design stellarator coils. The new coil design code, FOCUS, represents coils as arbitrary, closed, one-dimensional curves embedded in three-dimensional space. The target function to be minimized consists of multiple physical requirements and engineering constraints. By differentiating the first and second order derivatives of the target function with respect to coil parameters, FOCUS uses gradient-based and Hessian-based minimization algorithms to optimize the coils, fast and robustly. FOCUS has been validated by recovering the W7-X modular coils. It's being used to improve the coil design of HSX and explore the new type of resonant magnetic perturbation (RMP) coils on DIII-D tokamak.

By differentiating the optimal coil geometry with respect to the target surface, FOCUS could analyze the influence of changing plasma shapes on coil geometries. This could be used for an integrated design of the plasma and the coils. With semi-analytically calculated Hessian, FOCUS is able to use the eigenvalues of the Hessian matrix for determining the error field sensitivity to coil deviations. The sensitivities could provide information to avoid dominant coil misalignments and simplify coil designs for stellarators. A proof-of-principle example is given on a CNT-like configuration.