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Simplifying stellarator coils with plasma sensitivity information

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Coil complexity is one of the remaining challenges for stellarators. In coil design codes such as NESCOIL [1] and FOCUS [2], the primary figure of merit for evaluating how well coils produce the target magnetic field is the normal field error, which is the surface integral of residual normal magnetic field components on the plasma boundary. The surface integral assumes that plasma is equally sensitive to all normal perturbations, while the fact is not. Physical quantities like quasi-symmetry, magnetic islands, and MHD stability, which are crucial for successful stellarator operation, exhibit varying sensitivities to magnetic perturbations [3]. In this presentation, we present quantitative studies exploring the relationship between normal field errors and quasi-symmetry for a precisely quasi-axisymmetric configuration [4]. Our findings indicate that quasi-symmetry is more sensitive to specific perturbations. While reducing the surface integral of normal field errors leads to improved alignment with target values for relevant physical quantities, a more efficient approach is to optimize normal components with higher sensitivities. Utilizing plasma sensitivity information allows us to alleviate unnecessary constraints, thereby avoiding excessive coil complexity. Compared to the reference coil set [5], the new method obtains a new coil set that has equivalent quasi-symmetry with an 60% reduction in the averaged torsion. The new method provides insights for finding optimal coils that reduces engineering complexity while meeting physics requirements.

References

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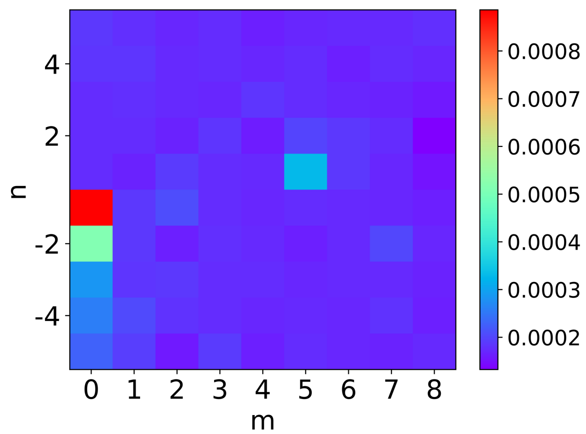

Figure 1 Changes in quasi-axisymmetry when applying an individual perturbation with a magnitude of 10^{-4}.

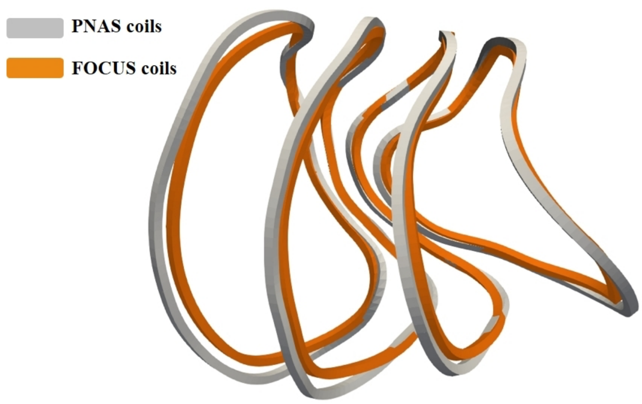

Figure 2 The new coil set (FOCUS coils) and the reference one (PNAS coils) have equivalent quasi-symmetry, but the FOCUS coils have a 60% reduction in the averaged torsion