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# FOCUS-HTS: A New Stellarator Coil Design Code for Three-dimensional High-Temperature Superconducting Magnets

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Stellarators mainly utilize magnetic fields from external coils to confine the plasma, enabling steady-state operation while avoiding instabilities like disruptions raised from plasma currents. Similar to tokamaks, the fusion power of stellarators is proportional to $R^3B^4$. High-temperature superconducting (HTS) coils can withstand high currents and thus offer significant advantages in enhancing fusion power or reducing the machine size. However, HTS materials, particularly Rare Earth-Barium-Copper Oxide (ReBCO), present unique electromagnetic and mechanical properties that pose new challenges for designing stellarator coils. To address these challenges, we developed a new code, *FOCUS-HTS*[1], built on its predecessor, FOCUS[2].

*FOCUS-HTS* can model coils as either filaments or finite-build shapes using the Fourier representation or cubic B-splines. In addition to standard physics and engineering targets, such as normal field errors, coil length, curvature and torsion, *FOCUS-HTS* can also optimize tape strains[3], electromagnetic (EM) forces[4], and critical current densities[5].

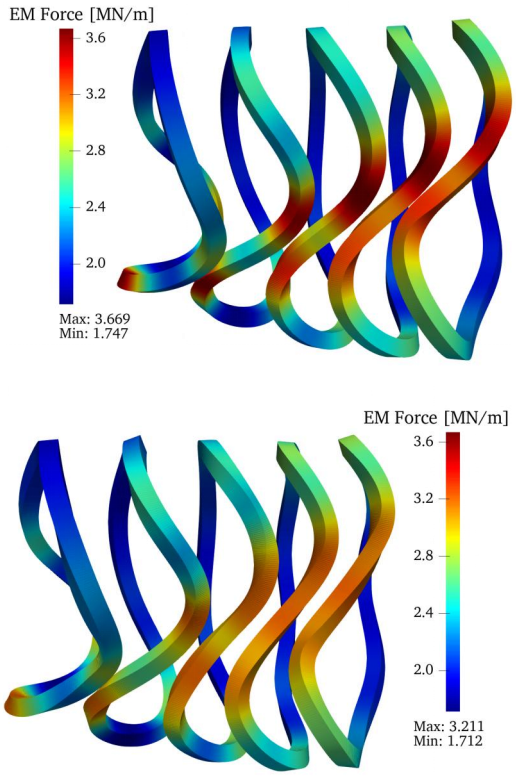


Figure 1. EM forces on the W7-X coils (up) and the force-reduced coils (down). The peak EM force is reduced from 3.669 MN/m to 3.211 MN/m and the average EM force is reduced from 2.545 MN to 2.331 MN.

Developed in Python with automatic differentiation (AD), the code allows easy interfacing and GPU acceleration. For demonstrations, *FOCUS-HTS* has been used to reduce the EM force of the W7-X coils and design HTS coils for a precisely quasi-axisymmetric stellarator[6]. Both examples demonstrate FOCUS-HTS' capabilities in reducing EM forces, controlling strain, estimating critical currents, and conducting comprehensive designs on existing stellarators and new devices.

References

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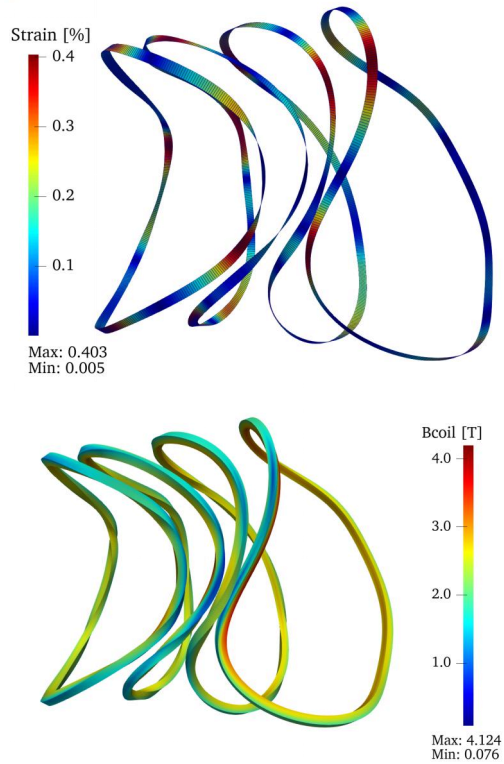


Figure 2. The strain (up) and the self-field (down) of precise-QA configuration coils optimized by *FOCUS-HTS* from circle coils. We included all constraints and finally obtained coils with the maximum strain of 0.403% and the max self-field of 4.124T.