Paths towards new quasi-axisymmetric stellarator designs

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An extensive study of quasi-axisymmetric equilibria has been conducted, from which a highly promising magnetic field design has been found by exploiting ROSE (Rose Optimizes Stellarator Equilibria) [1] – an optimization code for 3D magnetic plasma equilibria. The results of this design study and the characteristics of the new configuration [2] are presented.

Quasi-axisymmetric fields have small neoclassical particle losses thanks to a magnetic field strength which is independent of the toroidal Boozer coordinate. This toroidal symmetry causes quasi-axisymmetric stellarators to share many neoclassical properties with tokamaks such as a substantial bootstrap current, which produces positive rotational transform and thus helps to confine the plasma. In addition to the advantage of steady-state operation, there is experimental evidence that sufficient vacuum rotational transform can prevent certain types of disruptions – a major challenge for tokamaks.

The ROSE code optimizes the plasma boundary calculated with VMEC based on a set of physical and engineering criteria. Various aspect ratios, number of field periods and rotational-transform profiles have been investigated. As an evaluation of the design, the bootstrap current [3], ideal MHD stability [4], fast-particle losses [5], and the existence of islands [6] are examined. To the best of our knowledge, we have obtained better fast-particle loss-fraction rates than any previous quasi-axisymmetric configuration.

This study could form the basis of the design of a compact, MHD-stable, two-field-period stellarator with particularly good fast-particle confinement. As an extension to the optimization, which mainly concerned plasma physical properties, a new approach will also be presented that includes coil properties in the optimization procedure, which is one of the most demanding issues in stellarator design.

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