Quasi-isodynamic stellarator optimisation for several periodicities with a genetic algorithm

G. Godino[1], E. Sánchez[1], J.L. Velasco[1], S. Mulas[1]

[1] *Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain*

The stellarator is a reactor design concept to achieve controlled fusion by magnetic confinement. Despite several advantages over tokamaks, the lack of axisymmetry also creates some difficulties to confine the plasma: in a stellarator reactor, both thermal ions and the fast ions produced by DT fusion would be lost faster than in a tokamak. On the other hand, stellarators are characterized by a wider set of parameters that may be varied in an optimisation procedure to shape the magnetic configuration appropriately towards improved confinement. For thermal ions, optimisation to reduce neoclassical transport was shown to be effective for W7-X [1]; however, a stellarator with sufficiently reduced fast ion losses is yet to be designed.

This work involves the multi-objective optimisation of a stellarator device. To approach this problem, a single objective function is calculated as the weighted sum of squares of individual objectives, and its value is minimised with a global genetic algorithm (with differential evolution). Such a task requires simultaneously computing, on several radial positions, the properties of dozens of stellarator configurations, defined by hundreds of coefficients parameterising the last closed flux surface: thus requiring the use of parallelisation and the capabilities of HPC. The optimisation is carried out with the code suite STELLOPT [2] (CIEMAT branch), into which the neoclassical KNOSOS [3] has been incorporated, running on the CIEMAT cluster Xula.

The object of this work is to obtain stellarator configurations that display good confinement properties, particularly in terms of both thermal and fast ion confinement, while also satisfying the requirements of MHD stability. To this end, configurations are being pursued that follow the quasi-isodynamic concept with reactor relevant $\langle\beta\rangle \sim 4\%$ and aspect ratio near 10. In this contribution we will present results for 3, 5 and 6 periods. The main result is a particularly good 5 period configuration with lower effective ripple than W7-X in the plasma core and no losses of fast ions born at half radius up to 10ms, as verified by Monte Carlo full-orbit calculations with ASCOT [4]. The 3-period configuration has the advantage of being more compact than the 5 period design, although at the cost of some confinement capabilities.

References

[1] C.D. Beidler, H.M. Smith, A. Alonso et al. Nature **598**, E5 (2021).

[2] S. A. Lazerson et al. (www.osti.gov/biblio/1617636).

[3] J.L. Velasco et al. Nucl. Fusion **61** 116059 (2021).

[4] E. Hirvijoki et al. Comput. Phys. Commun. **185** 1310 (2014)