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Quasi-isodynamic stellarator optimisation for several periodicities

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The stellarator is a device designed to achieve controlled fusion by magnetic confinement.
Despite several advantages over tokamaks, its lack of axisymmetry creates some difficulties to confine the plasma: in an unoptimised 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 characterised 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 has been shown to be effective for Wendelstein 7-X [1]; however, a stellarator with sufficiently reduced fast ion losses and low turbulent transport is yet to be built.

The object of this work is to obtain stellarator configurations that display good properties, particularly in terms of both thermal and fast ion confinement, while also satisfying the requirements of magnetohydrodynamic stability as determined by the Mercier criterion. To
this end, configurations are being pursued that follow the quasi-isodynamic (QI) concept and fulfil, already from intermediate $\langle\beta\rangle$, the maximum-J property. The closeness to QI serves to reduce neoclassical transport and maintain a low bootstrap current. We intend to allow for an island divertor design by having a monotonically increasing rotational transform profile which avoids low-order rationals and approaches 1 at the last closed flux surface, whereas the smallness of the bootstrap current is desirable to avoid unwanted changes to said profile. Additionally, the maximum-J property is expected to improve fast ion confinement and reduce turbulent transport. The design parameters chosen include an aspect ratio near 11-12 and a limited maximum elongation of the flux surfaces. The optimisation was carried out at an intermediate value of $\langle\beta\rangle$=2.5% as a strategy to maintain good properties for both intermediate and reactor relevant plasma pressures.

This optimisation work uses the code suite STELLOPT (CIEMAT branch), into which the neoclassical code KNOSOS [2] has been incorporated. The resulting configurations belong to the family of flat-mirror QI configurations [3], like the recently published design [4]. This contribution includes results for several periodicities. The main result is a particularly good 5 period configuration with small effective ripple (the figure of merit for neoclassical bulk energy transport) in the plasma core and no prompt losses of fast ions born at half radius, as verified by Monte Carlo guiding-centre simulations at reactor $\langle\beta\rangle$. This design also displays a low bootstrap current and fulfils the rotational transform requirements. The 3-period configuration has the advantage of being more compact than the 5 period design, although at the cost of some confinement capabilities. Finally, the 6 period configuration has similar confinement capabilities to the 5 period design at reactor $\langle\beta\rangle$.

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