Reactors with Stellarator Stability and Tokamak Transport

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The discovery of quasiaxially symmetric stellarators (QAS), for which the spectrum of the magnetic field has approximate two-dimensional symmetry, opens up the possibility of designing fusion reactors that have tokamak confinement and stellarator stability. This may enable power plants to operate in a steady state at high β without disruptions. We have developed stellarator reactors that possess these characteristics and have two or three field periods. The configurations are compact, with aspect ratios ranging from as low as 3 up to as high as 6. The rotational transforms ι are in the ranges $0.55>\iota>0.4$ and $0.7>\iota>0.4$ for the two and three field period configurations, respectively. The asymmetric terms in the magnetic spectrum, which can be less than one percent, are almost as small as the coefficients for a typical tokamak that are associated with ripple from the toroidal coils or helical excursion of the magnetic axis resulting from MHD instability. Reactors yielding 1 GW of electric power appear to be possible with major radius ~7 m.

We have also developed preliminary designs of the coils that are required to shape the plasma for overall systems analysis and engineering studies. Solutions with only twelve coils have been found for the two field period configuration. These modular coils are only moderately twisted, producing robust flux surfaces that do not deteriorate when changes are made in the vertical and toroidal fields. Filaments specifying the coils have a distance from the separatrix exceeding 1.4 m for a reactor with R~7 m. There is adequate room for radiation shielding to protect the coils and for the breeding blanket to produce tritium.

Recent LHD and W7-AS experiments have observed high β values which exceeded the limit predicted by numerical solutions based on linear, ideal MHD theory. The problem may be that force balance and stability are lost across islands if the equilibrium equations are not in conservation form. In light of the new experimental results, we shall discuss nonlinear MHD stability analysis with the NSTAB code, which employs a conservation form of the magnetostatic equations to calculate weak solutions that capture discontinuities modeling effectively both current sheets and small chains of magnetic islands. The application of NSTAB computations to the design of stellarator reactors will be illustrated.