Energetic Particle Transport and Alfvén Instabilities in Compact Stellarators

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Stellarator design tools have evolved in recent years to allow the development of a number of new compact stellarator configurations (QPS, NCSX) that maintain good plasma neoclassical confinement while improving on various shortfalls of the tokamak (e.g., absence of disruptions, stability to neoclassical tearing instabilities, lowered poloidal flow damping). These improvements have been possible due to the development of rapidly evaluated optimization targets for thermal plasma stability and transport. In the case of energetic particle confinement and stability, efficiently evaluated target functions remain to be developed and, as a result, energetic particle physics issues must be evaluated a posteriori. Significant issues include: classical confinement of energetic ions during slowing-down, Alfvén gap modes, interaction of fast ions with plasma MHD modes, energetic electron tail confinement and impact of energetic ions on core transport properties (i.e., parallel viscosity, bootstrap current). We have developed tools to address a number of these issues. These include an efficient parallel/vectorized fast particle Monte Carlo code (DELTA5D) and an Alfvén gap stability code (STELLGAP). These codes have been applied both to compact stellarators (QPS, NCSX) and to a variety of existing experiments (CHS, LHD, W7-AS, TJ-II, HSX). This analysis can lead to the development of optimization target functions that can be useful in flexibility studies and in the design of future devices.

Tokamaks with broken symmetry provide an additional important set of 3D configurations that can be analyzed by the above tools. Symmetry breaking effects can arise from toroidal field ripple, vacuum chamber breaks and port structures, and internal MHD instabilities. Such effects can strongly impact energetic particle confinement and heat load patterns on the vacuum chamber wall. Results from these studies will be discussed as well as plans for future developments of these models.

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