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Healing of magnetic islands in stellarators by plasma flow[1]

C.C. HEGNA, University of Wisconsin

Recent experiments from the Large Helical Device (LHD) demonstrate a correlation between the "healing" of vacuum magnetic islands in stellarators and changes in the plasma flow. In the LHD experiments, external 3-D coils are intentionally applied to produce magnetic islands in the vacuum configuration. With plasma, both island growth and healing is seen with the two disparate plasma responses distinguished by a sharp boundary in a parameter space defined by the plasma β and collisionality at the rational surface. While island growth is observed at low β and high collisionality, at sufficiently high β and/or low collisionality, the plasma abruptly changes to a configuration with no island. A model explaining this phenomenon is developed reminiscent of "mode locking/unlocking" theory of tokamak physics. The theory describes transitions between two asymptotic solutions, a state with a large nonrotating island and a state where rotation shielding suppresses island formation. Transitions between these two states are governed by coupled torque balance and island evolution equations. In conventional stellarators, neoclassical damping physics plays an important role in establishing the flow profiles. The balance of neoclassical damping and cross-field viscosity produces a radial boundary layer for the plasma rotation profile outside the separatrix of a locked magnetic island. The width of this boundary layer decreases as the plasma becomes less collisional. This has the consequence of enhancing the viscous torque at low collisionality making healing magnetic islands occur more readily in high temperature conventional stellarators. The analytic theory produces a critical β for healing [$\beta_{crit} \sim (\nu^*)^{1/4}$] that is in qualitative agreement with LHD observations.

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