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Plasma Disruption Avoidance and Mitigation using Strong Non-Axisymmetric Shaping with Stellarator Fields

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The avoidance and mitigation of major disruptions remains a critical challenge for ITER and future burning tokamak plasmas. Early stellarator experiments with toroidal plasma current were found to operate without disruptions if the vacuum rotational transform produced by external coils was greater than a threshold value of $\iota_{\mathrm{vac}}(a) \geq 0.14$ [1]. Strong 3-D shaping produced by externally generated rotational transform is also observed to suppress disruptive phenomena of current-carrying discharges in the Compact Toroidal Hybrid (CTH), with the amount of $\iota_{\mathrm{vac}}(a)$ required for suppression dependent upon the disruption scenario. Current-driven disruptions are deliberately generated in CTH by (1) raising the plasma density, (2) operating at low edge safety factor $q(a)$, or (3) by not compensating against the vertical instability of plasmas with high elongation. While the density limit is found to agree with the empirical Greenwald limit at low edge vacuum transform ($\iota_{\mathrm{vac}}(a) = 0.04$), the experimental densities exceed this limit by up to a factor of three as the vacuum transform is raised to $\iota_{\mathrm{vac}}(a) = 0.25$. Low-$q$ disruptions near $q(a) = 2$ are observed at low vacuum transform but no longer occur when the vacuum transform is raised above $\iota_{\mathrm{vac}}(a) > 0.07$, even though $q(a)$ falls below a value of 2. Passive suppression of the vertical instability of elongated plasmas is observed with the addition of external transform, and the amount required is in agreement with an analytic calculation of marginal stability in current-carrying stellarators [2].

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[2] G. Y. Fu, Phys. Plasmas **7**, 1079 (2000).