Control of DIII-D Advanced Tokamak Discharges*

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A key goal in control of an advanced tokamak (AT) discharge is to maintain safety factor (q) and pressure profiles that are consistent with both MHD stability at high beta and a high fraction of the self-generated bootstrap current. This will enable noninductive sustainment of 100% of the plasma current, as has been demonstrated at high beta ($\beta = 3.6\%$, $\beta_N = 3.4$) in DIII-D for up to 1 s [1]. The aim is to create the desired q profile during the discharge formation and sustain it using electron cyclotron current drive (ECCD), bootstrap current and neutral beam current drive. The time evolution of the q profile during the formation is modified through feedback control of β. Other techniques for control of the q profile have been tested in L-mode cases where the effect of the available gyrotron power is relatively large. Control of the time evolution of q(0) during the current ramp-up has been demonstrated using off-axis ECH to modify the electron temperature and thus the rate of current penetration. Avoidance of an increase in q(0) when high power ECCD is applied has been investigated using feedback controlled modification of the rate of increase of the ECCD power to account for the inductive response on axis. Control of the pressure profile shape is aimed at maintaining broad profiles. Modeling has demonstrated that with $q_{min} > 2$, $\beta_N = 5$ is possible with a sufficiently broad pressure profile, while in the experiment $\beta_N = 4$ with $q_{min} = 2$ has been achieved with $P(0)/\langle P\rangle = 2.3$ [2]. Tools for pressure profile control are being implemented including real time acquisition of the T_e, n_e, T_i and rotation profiles and modification of two neutral beam sources to counter-injection. Simultaneous feedback control of T_e at two spatial locations has been demonstrated using off-axis and on-axis ECH.

[1] M. Murakami, *et al.*, "100% Noninductive Operation at High Beta Using Off-Axis ECCD," submitted to Nucl. Fusion (2004).
[2] J.R. Ferron, et al., "Optimization of DIII-D Advanced Tokamak Discharges With Respect to the Beta Limit," to be published in Phys.Plasmas (2005).

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