Advanced Tokamak Physics on DIII–D*

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The advanced tokamak (AT) regime promises to increase the attractiveness of the steady-state tokamak by simultaneously achieving high beta and a high bootstrap current fraction with good confinement. This requires that the normalized beta (β_N) and normalized confinement (H) have values about twice that of the conventional tokamak regime. Experiments to date have achieved $\beta_N H > 9$ for more than 2 seconds in plasmas with an ELMing H–mode edge. Recent experiments on DIII–D have improved our understanding of the transport, stability, and current profile evolution of the AT regime. The internal transport barrier which leads to excellent core confinement can be formed by either increasing the E×B flow shear or by reducing the growth rates of the plasma turbulence. Many factors such as impurity concentration and the ion-to-electron temperature ratio can influence the growth rates. The E×B flow shear was varied by changing the NBI from co to counter which broadened the ITB region in the plasma. In addition to controlling the E×B flow shear, experiments will be performed to vary the width of the ITB by using localized heating outside the transport barrier region. The value of β_N in recent AT plasmas was not limited by the neoclassical tearing mode or edge instability as found previously, but rather by the resistive wall mode. This represents the ultimate beta limit that can be reached since beta is measured to be above the no-wall limit ($\beta_N > 4\ \ell_i$) for more than 2 seconds. Experiments are continuing to utilize active control to stabilize the resistive wall mode. The improvement of $\beta_N H$ above previously attained values on DIII–D for long duration AT discharges is due to this increase in the normalized beta. The loop voltage profile, determined from the evolution of the poloidal magnetic flux, for these long duration AT discharges is measured to be negative in the plasma center and edge region. Therefore, to attain steady state in the current profile evolution off-axis current drive is required. Experiments will be performed to substitute off-axis ECH for some of the NBI power to attain a stationary current profile. Measurements of off-axis ECCD to date support this plan, with localized current drive measured using the MSE diagnostic. The measured ECCD efficiency is equal to or greater than the calculated efficiency from Fokker-Planck codes, and the current drive width was at least as narrow as theory. A remaining challenge is to increase the temperature by reducing the density using the divertor cryopump to aid the off-axis ECCD.

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