Abstract for an Invited Paper
for the DPP07 Meeting of
The American Physical Society

Advancing Tokamak Physics with the ITER Hybrid Scenario on DIII-D[1]

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Recent DIII-D experiments using hybrid scenario plasmas (hybrids) have furthered our understanding of transport and stability in high beta tokamaks, leading to the possibility of high fusion performance on ITER. The hybrid is a stationary, inductively driven, $q_0 \sim 1$ discharge with better confinement and stability than standard H-mode. Providing stationary, high beta conditions, the hybrid is an excellent configuration for study of tokamak plasma physics under conditions of interest to burning plasmas, such as low rotation, balanced T_e and T_i, shaping, and pedestal behavior. Compared to a standard H-mode, the hybrid has a broader current profile, reducing or eliminating the deleterious effects of sawteeth, and is less susceptible to $m/n = 2/1$ NTMs, allowing higher β operation. Our experiments have conclusively shown that the current profile is broadened by a relatively benign $m/n = 3/2$ NTM. Power balance in hybrids is dominated by electron heat conduction, but the observed electron thermal diffusivity is relatively small, and the ion thermal diffusivity is consistently at or close to the neoclassical value. Using the recent modification to the DIIID neutral beam configuration, we have been able to reduce the toroidal rotation velocity to a central Mach number <0.1, under stationary conditions. We find that confinement improves with increasing rotation. Gyrofluid simulations indicate that this is associated with the change in ExB flow shear. The width of the NTM island decreases as rotation and rotation shear are increased. However, the difference in the fusion performance parameter G ($=\beta_N \cdot H/q^2$) at low and high rotation is only 10%-30%. Thus, although rotation and rotation shear are important parameters for improving tokamak performance, good confinement and stability can be maintained even in their absence.

[1]Supported by US DOE under DE-FC02-04ER54698.