Effects of Toroidal Rotation on Hybrid Scenario Plasmas*

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Based on experiments on the DIII-D tokamak, a long duration, high performance plasma discharge has been developed as an attractive operating scenario for ITER. This "hybrid" scenario regime is inductively driven, with bootstrap current fraction of 0.3-0.5 and a fully relaxed current profile with $q_0 \sim 1$. Compared to standard H-mode operation, the hybrid plasma has a broader current profile. This makes it less susceptible to $m/n = 2/1$ NTMs, allowing higher β operation, and (at $q95 > 4$) eliminates sawteeth, improving overall confinement and removing a trigger for the 2/1 NTM. At $q_{95} \approx 3.2$, the fusion performance parameter G ($= \beta_N H_{89P}/q_{95}^2$) has been maintained at $G = 0.7$ with stationary conditions for over five current relaxation times, well above the value of $G = 0.42$ projected for ITER operation at $Q_{fus} = 10$.

The experience base for hybrid plasmas has been limited to plasmas with strong toroidal rotation, using significant levels of NBI co-injection to maintain high torque. Rotation studies in hybrids are motivated by both tests of theory and by concerns about projections to ITER, which may have low toroidal rotation. In recent DIII-D experiments we have studied the changes in characteristics and performance of hybrid plasmas as the applied NBI toroidal torque is varied. We have reduced the toroidal rotation velocity (v_ϕ) a factor of ~6, to $M_0 \approx 0.075$, under stationary conditions. With low rotation, confinement is reduced and the width of the NTM island increases. This behavior is independent of the means used to slow the plasma. Transport continues to be dominated by electrons, and simulations using GLF23 confirm that the change in ExB shear can account for much of the change with rotation. These observations provide optimism about the projections of the hybrid scenario to low rotation plasmas in ITER, but they also indicate the need for a better understanding of the physics of toroidal rotation – both momentum transport and the impact of rotation on other aspects of performance.

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