Resistive Wall Mode Stabilization and Plasma Rotation Damping Considerations for Maintaining High Beta Plasma Discharges in NSTX *

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Abstract: Maintaining steady fusion power output at high plasma beta is an important goal for future burning plasmas such as in ITER advanced scenario operation and the Fusion Nuclear Science Facility. Research on the National Spherical Torus Experiment (NSTX) is investigating the stability physics and control to maintain steady high plasma normalized beta greater than 5 with minimal fluctuation. Resistive wall mode (RWM) instability is observed at relatively high rotation levels. Analysis including kinetic dissipation effects using the MISK code shows a region of reduced stability for marginally stable experimental plasmas caused by the rotation profile falling between stabilizing ion precession drift and bounce resonances. Collisionality alters the dependence of RWM stability on rotation. Energetic particle (EP) effects are stabilizing and weaker than in tokamaks due to a reduced EP population in the outer plasma. Calculations for ITER show that alpha particles are required to stabilize the RWM at anticipated rotation levels for normalized beta of 3. Non-resonant braking by applied 3-D fields could be used to actuate rotation control and avoid rotation profiles unfavorable for RWM stability discussed above. Recent experiments have varied the ratio of ion collisionality to ExB frequency. As the ExB frequency is reduced, the NTV torque is expected to increase as collisionality decreases, and maximize when it falls below the grad(B) drift frequency (superbanana plateau regime). Increased non-resonant braking was observed at constant applied field and normalized beta in experiments when rotation and ExB frequency were reduced to low values (most applicable to ITER) as expected by theory. The newly-developed multi-mode VALEN code is used to analyze high normalized beta experiments showing evidence of driven RWM activity. The computed RWM growth rate vs. normalized beta is in the observed experimental range. The computed spectrum of eigenfunctions comprising the perturbed field shows significant multi-mode content. Using this model, multi-mode RWM stability is determined for ITER advanced scenario plasmas at normalized beta sufficient to destabilize n = 2 modes. Combined RWM and new beta feedback control capability were used to generate high pulse-averaged normalized beta with low fluctuation. NTV braking was used to alter plasma rotation compatibly with beta feedback, as steady rotation with long pulse duration was produced at varied rotation levels.

*Supported by US DOE Contracts DE-FG02-99ER54524 and DE-AC02-09CH11466.