Influence of plasma flow shear on tearing in DIII-D hybrids

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Abstract. That plasma flow shear has a stabilizing effect on tearing stability is a new insight found from experiments on DIII-D, JET, and NSTX. High-order (m/n = 4/3 or 3/2) tearing modes are a key beneficial feature in hybrid scenarios that act to regulate the q-profile to keep $q(0)$~1 with the absence of large m/n = 1/1 sawteeth. The destabilization of low-order (m/n = 2/1) tearing acts as the limit on achievable beta. Hybrid discharges in DIII-D with 4/3 tearing modes under large co- (to I_p) neutral-beam torque can be run steadily just below the 2/1 tearing beta limit. However, reducing the torque has consequences on both the existing 4/3 tearing mode amplitude and the beta at which the 2/1 tearing mode destabilizes. It is found that flow *shear* at a rational surface is well correlated with both decreased 4/3 mode amplitude and higher beta 2/1 mode onset. The working physics model is that flow shear is classically stabilizing, i.e., makes the tearing stability index Δ' more negative; this both reduces the amplitude of neoclassical tearing modes and makes mode destabilization more difficult (requiring higher beta). However, a detailed understanding of the effects of flow shear on tearing stability remains a challenge for theory and modeling. The classically stabilizing effect of flow shear in DIII-D (and indeed future larger tokamaks) is in the regime of large magnetic Prandtl and very large Lundquist numbers; this is significant for sorting out which physical effects of flow and flow shear are relevant and would be stabilizing or even destabilizing. Experimental data with applied torque varied from all co- to near-balanced neutral beams in the DIII-D hybrid scenario with 4/3 mode "regulation" is analyzed for 4/3 mode amplitude, 2/1 onset, and criticality for 2/1 mode locking. For both existing m/n = 4/3 modes and for the onset of m/n=2/1 modes, a local flow shear of the order of $-\tau_A^{-1}/4L_s$ is found to have a significant stabilizing effect on tearing. In addition, a flow shear effect increasing local viscosity is suggested in order to explain the behavior of mode locking to the resistive wall.