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Islands in the Stream: The Effect of Plasma Flow on Tearing Stability[1]

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Reducing plasma flow clearly decreases the stability of tearing modes in multiple regimes (sawtooth, hybrid) in both high- and low-aspect-ratio tokamaks (DIII-D, JET, NSTX, each with distinct means of lessening rotation). Further, reducing flow makes preexisting "saturated" islands larger at the same beta. Thus lower plasma flow impairs high-beta operation owing both to the destabilization and to the impact of tearing-mode islands. The physics is that *flow shear* (not flow) at the tearing rational surface is classically stabilizing, making the tearing stability index Δ' more negative (more stable). In this picture, with profiles and all else the same, the critical beta at which neoclassical tearing modes (NTMs) destabilize is proportional to $-\Delta'$ and hence lower flow and flow shear lead to destabilization at lower beta. Similarly, if destabilized, the saturated NTM island width is proportional to $-\beta/\Delta'$ and thus increases as flow and flow shear are reduced. A working model for a significant level of stabilizing shear in the plasma toroidal angular flow $-d\Omega_\phi/dr$ at a given rational surface is of order of the inverse of the product of the local values of the parallel magnetic shear length L_s and the Alfvèn time τ_A. Experimental data are fitted for the effect of this normalization of flow shear in a simple empirical model for both onset and saturation of tearing modes. Most theoretical literature is on the consequence of flow shear on classical tearing stability at zero beta; tokamaks at high beta have large magnetic Prandtl number (an issue for the sign of the flow effect) and very large Lundquist number. It is in this regime that theory will be compared to experimentally based empirical models. The consequence for future tokamaks with low rotation may be lower tearing stability than now expected.

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