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Interaction of plasma rotation and resonant magnetic perturbation fields in Tokamaks

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The interaction between the poloidal or toroidal rotation and external magnetic perturbation fields is an important issue for fusion oriented devices and is therefore under investigation experimentally and theoretically.

Here this interaction is described by the ambipolarity constraint, the parallel ion momentum balance, both emanating from the revisited neoclassical theory, and the electrodynamic screening of the the resonant field at the singular surfaces mainly depending on the difference between the rotation frequencies of the plasma and the helical field. As in Ref. /1/ the screening is accounted for by assuming the tearing stability index, Δ', to be negative. The revisited neoclassical theory valid in the collision dominated regime and accounting for gyro viscosity was extended to include arbitrary plasma cross - sections, anomalous viscosity, ponderomotive forces, and the momentum source due to ergodicity which has a considerable impact on the toroidal velocity v_t as demonstrated in TEXTOR.

The ripple of the toroidal field can be included as a (high n) perturbation.

To estimate the influence of the perturbation coils on the plasma rotation, the radial magnetic field are expanded in Fourier harmonics (using 'intrinsic' coordinates) and the total field is used for field line tracing thus obtaining the ponderomotive momentum input and the extension Δ_m and the magnetic diffusion coefficient D_M of the ergodic layer at the edge. Both procedures account for the full plasma geometry. Δ_m and D_M are assumed to be independent from the rotation speed because of the boundary condition $v_t(a)$=0. (a is the effective plasma radius.) In a second step the obtained velocity profiles are used to compute the screening at the singular layers and thus the reduction of the island width due to plasma rotation.

The main results can be summarized as follows:
Using in the case of the TEXTOR shot #94092 the diffusion coefficient D_M= 2 x 10^{-6} m (typical for the {m=12, n=4} configuration) the observed increase of v_t by $\Delta v_t \approx 5\frac{km}{sec}$ can be reproduced. The large screening due to toroidal rotation ($v_{t_{max}} = 120\frac{km}{sec}$) inside the plasma prevents any influence of the ponderomotive forces, thus yielding a constant increase of the $v_t(r)$ - profile by Δv_t.
Assuming in the case of the error field correction coils (n=1) of JET the current I_{hel}= 20 kA and the plasma rotation of shot #59316 ($v_{t_{max}} = 220\frac{km}{sec}$) reduces the island width e. g. at the rational surface q=2 to a negligible value. In the vicinity of the X - point $\Delta_m \approx 10\ cm$ is obtained. This may be important for the ELM- mitigation.

/ 1/ R. Fitzpatrick, Phys of Plasmas, 4, 4325 (1998)