Program for Finding the Upper Bound on Unstable Alfvén Mode Induced Fusion Alpha Transport Losses*

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Previous GYRO simulations have shown that reactor-scale fusion alpha transport from thermal plasma instabilities like ITG/TEM is likely to be insignificant [1]. Recent simulations of fixed gradient alpha transport induced by alpha driven local (very low- $k_α ρ_s$ but high- $n$ for low- $ρ$) Alfvénic TAE/EPM turbulence embedded in very strong (moderate- $k_α ρ_s$) ITG/TEM turbulence showed nonlinearly saturated states can exist at energetic particle (EP) pressures up to perhaps twice the TAE/EPM stability threshold with quasi-linear (and likely intermittent) relaxation of the driving EP pressure gradient appearing at stronger EP drive [2]. However, even the pre-relaxation level of EP transport is not significantly higher than the ITG/TEM induced level below the local linear TAE/EPM threshold EP pressure gradient $-dP_{α}^{loc-lin}/dr$. Since the global linear stability threshold will always exceed that for the local, $-dP_{α}^{loc-lin}(r)/dr$ should provide an upper bound on unstable Alfvén mode induced fusion alpha transport losses: Given the MHD equilibrium and thermal plasma profiles, it is straightforward to calculate the local fusion energy deposition rate $Q_{α}(r)$ [MeV/sec/m³], the classical slowing-down fusion alpha density profile $n_{α}^{class}(r)$, and the effective alpha temperature profile $T_{α}^{class}(r)$ (which has a very weak gradient). Since $-T_{α}^{class} dn_{α}^{class}(r)/dr$ will be less than $-dP_{α}^{loc-lin}(r)/dr$ beyond some outer radius, $n_{α}(r)=n_{α}^{class}(r)$ for $r>r_b$. Integrating $-dn_{α}(r)/dr=[-dn_{α}^{class}(r)/dr,-dn_{α}^{loc-lin}(r)/dr]_{min}$ inward from $r=r_b$, the maximum $n_{α}(r)$ will be less than $n_{α}^{class}(r)$ for $r<r_b$. Since the effective alpha temperature should not deviate from $T_{α}^{class}(r)$, the minimum fusion energy deposition rate to the thermal plasma is $[n_{α}(r)/n_{α}^{class}(r)]Q_{α}(r)$ from which an upper bound on alpha transport losses can be inferred. Physically accurate gyrokinetic $-dP_{α}^{loc-lin}(r)/dr$ profiles from TGLF projected ITER plasma profiles are easily obtained [3].


*Work supported by the US Department of Energy under DE-FG02-09ER54309 and by US DOE-SciDAC Gyrokinetic Simulation Energetic Particle (GSEP) project under DE-FC02-08ER54963.