Impurity radiation seeded neoclassical tearing mode growth

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The magnetohydrodynamic instability of tearing mode is of great concern to the magnetic confined fusion plasma, which leads to the degradation of the plasma confinement and even major disruption to terminate the discharge, especially in the burning plasma regime, i.e. the neoclassical tearing mode (NTM)[1]. However, the critical physics of the seed island required for the NTM growth yet remains elusive despite continued and intensive interests.

Recent NIMROD simulations have demonstrated that the local impurity radiation cooling drives the seed island growth[2,3], and triggers the subsequent onset of neoclassical tearing mode instability. The seed island is mainly driven by the local helical current perturbation, which is essentially the diamagnetic current induced by the perturbed pressure gradient as a result of the modification of local force balance from impurity radiative cooling around the rational surface. The island growth is consistent with the original Rutherford model for the resistive tearing mode except near the peaking time (Figure 1).

A heuristic closure for the neoclassical viscosity is adopted, and the seed island is further driven by the perturbed bootstrap current modeled by the neoclassical electron viscous stress in the extended Ohm's law (Figure 2). The NTM growth rate in simulations is found proportional to the electron neoclassical viscosity, and a neoclassical driving term in the modified Rutherford equation is used to account for the NTM island growth in comparison with the simulations. The simulation and analysis are applied to the explore of impurity radiation seeded NTM growth on the China fusion engineering test reactor (CFETR) hybrid scenario.

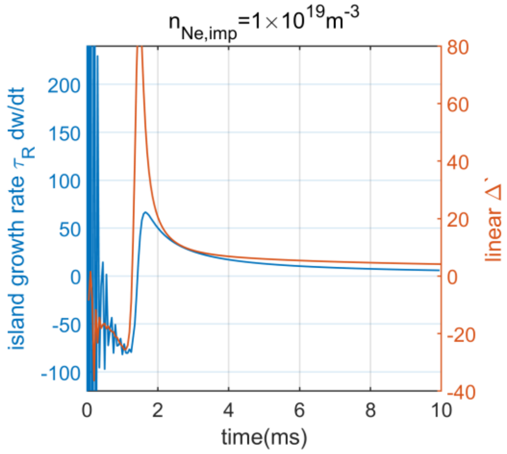

Figure 1. The resistive magnetic island growth rate (blue line) and the linear tearing stability parameter (orange line) as functions of time, here the coefficient $\mu_e = 0$.

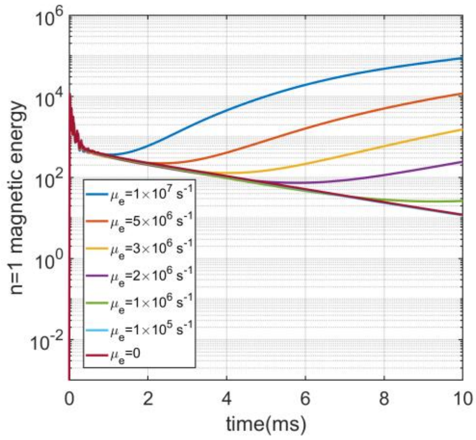

Figure 2. The n=1 component of magnetic energy as functions of time with different values of the coefficient μ_e.

References
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