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Influence of deeply trapped energetic ions on tearing modes

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A tearing mode, accompanying the reconnection of well-nested magnetic flux surfaces, is one kind of the most dangerous magnetohydrodynamic (MHD) instabilities in fusion plasma.[1,2] It may signifificantly degrade the confifinement of plasma particles and energy by increasing the local radial transport. It can also have serious impacts on the performance of tokamak discharge. Actually, many disruption events have been caused by tearing modes, including neoclassical tearing modes (NTMs).[3,4] The loss of energetic particles can affect the performance of fusion devices in several ways. First, if the expulsion of energetic particles is intense and localized enough, it can damage the plasma-facing components of the reactor. Besides, the radial transport of energetic. The interaction between MHD instabilities and energetic particles is of special importance in burning plasmas with a large population of a-particles as in ITER. MHD instabilities can be driven by energetic particles[5-7], and they can also lead to an enhancement of fast-ion radial transport.

The effects of deeply trapped energetic ions (DTEIs) on the stability of tearing modes through stability criterion Δ' are studied. In contrast to the stabilizing adiabatic effect of background plasma pressure, the adiabatic contribution of the DTEI destabilizes due to the direct coupling between the bad curvature and asymmetrical pressure of energetic ions. When the orbit width is much larger than the island width, the non-adiabatic effect of the DTEI stabilizes, which counteracts the major destabilizing adiabatic contribution. DTEIs are shown to have a net destabilizing effect on the tearing mode. The main physics of destabilization of Δ' comes from the modification of the Mercier index.

Figure 1(a) illustrates the stability criterion of tearing modes, $\Delta_\beta{}'$, against the parameter χ with different DTEI pressure fractions β^h_{frac}. In Fig. 1(a), it is shown that for a given value of β^h_{frac} , $\Delta_\beta{}'$ increases monotonically with χ. Besides, for the same χ, the stability parameter $\Delta_\beta{}'$ also increases with the increasing fraction of DTEI β^h_{frac}. $\Delta_\beta{}'$ as the crucial measure of the plasma free energy is essential for the stability of classical tearing modes and the onset as well as the evolution of NTMs. Strictly speaking, an increased $\Delta_\beta{}'$ (positive value) implies an unstable trend of the tearing mode when the mode is stable initially. The increased $\Delta_\beta{}'$ implies a more unstable tearing mode when the mode is unstable initially. The more unstable tearing mode may provide the seed islands for NTMs and can be one of the onset mechanisms of spontaneous NTMs. It can be seen that the net effect of the DTEI destabilizes for tearing modes. The effect of DTEI becomes insignifificant for $\chi <$ 0.5.

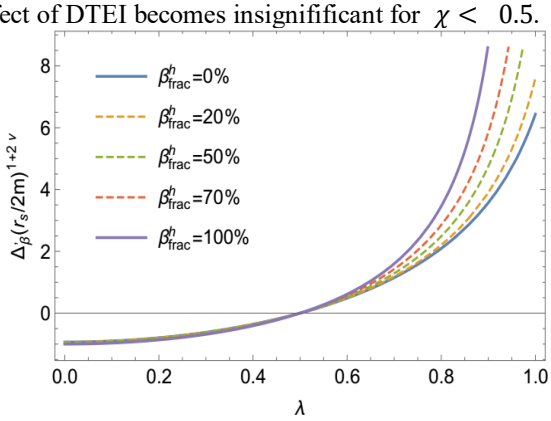

FIG. 1. The functions $\Delta_\beta{}'$ vs χ for different values of β^h_{frac} . They are denoted by $\beta^h_{frac} = 0$ (solid blue line), $\beta^h_{frac} = 20\%$ (dashed orange line), $\beta^h_{frac} = 50\%$ (dashed Green line), $\beta^h_{frac} = 70\%$ (dashed red line), and $\beta^h_{frac} = 100\%$ (solid purple line). Note that the threshold condition for these cases is the same $\chi = 0.5$ as it is in the zero beta case.

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