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Enhancement of ECCD by the current condensation effect for stabilizing large magnetic islands caused by neoclassical tearing modes in tokamak plasmas

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In order to achieve self-sustained burning in ITER and future large-scale devices, good confinement will be essential. These devices will operate at low collisionality and at sufficiently high pressure to drive substantial bootstrap current. The large bootstrap current poses a threat in the form of neoclassical tearing modes (NTMs). With the aim of the mitigation and/or active control of NTM for disruption avoidance, electron cyclotron current drive (ECCD) has been brought forward. Although ECCD is proven to be effective to stabilize NTMs both in experiments and in simulations, off-normal events that can cause extremely large islands is still challenging to control in future large-scale devices such as ITER.

Recently, Reiman et al. found a radio frequency current condensation effect that can nonlinearly enhance the stabilizing efficiency of ECCD so that the extremely large islands are expected to be effectively controlled. The radio frequency current condensation effect reported in [1] is modelled in the nonlinear resistive MHD code MHD@Dalian Code [2-4]. A series of numerical investigations have been performed to investigate the enhancement of ECCD by the current condensation effect during the control of NTMs in tokamak plasmas. In the numerical model, both the parallel transport and the perpendicular transport of electron temperature are considered. The EC driven current and driven perturbed electron temperature can nonlinearly evolve within the given magnetic configuration and eventually reach saturation states. The input power threshold of ECCD and the fold bifurcation phenomenon (shown in figure 1) are numerically verified via nonlinear simulations. The numerical results show good agreements with the analytical results. Moreover, spatial distributions of EC current for the two solutions at different condensed level are displayed. The control effectiveness of ECCD for large NTM islands has been evaluated while considering the current condensation effect. While taking into account current condensation effect, for a given input power, a larger island can be more effectively stabilized than a smaller one, which suggests a reassessment of the previous idea that the ECCD should always be turned on as early as possible. The potential physics mechanism behind the ECCD control have all been discussed in detail. Furthermore, the condensation effect is found to have favorable effects on the radial misalignment of ECCD. In the consideration of the situation for extremely localized control needs, a highly peaking heating profile is adopted to verify that the fold bifurcation phenomenon still exists and the current condensation effect can still take effect in this extreme condition.

The work described here is the first to use a nonlinear resistive MHD code in the modeling of the current condensation effect. The investigations manifested that the current condensation effect can be more effective for the ECCD control of large NTM islands. Considering the larger the island is, the effectiveness and efficiency of ECCD is more enhanced, the condensation effect is expected to play important roles in dealing with off-normal events in future large-scale devices.

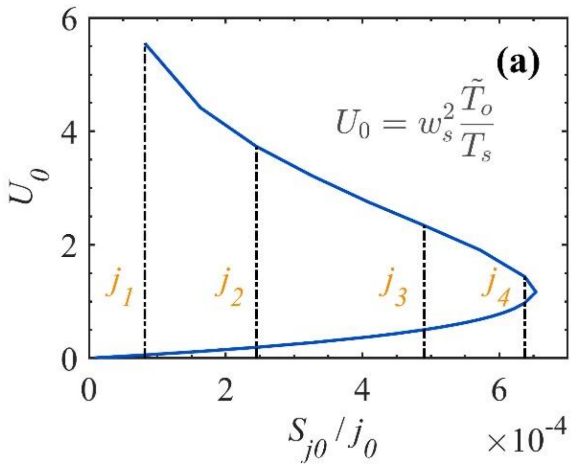

Figure 1. The fold bifurcation phenomenon.

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