Nonlinear MHD simulation of core plasma collapse events in stellarators

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Nonlinear dynamics of core plasma collapse events in stellarators are studied using a 3D nonlinear MHD simulation code. In stellarator experiments, some plasma core collapse events were observed. For example, in the Large Helical Device (LHD) experiment, a collapse event in the core plasma density was observed for pressure profiles peaked by pellet injection. A nonlinear resistive MHD simulation confirmed that this collapse event is driven by a resistive ballooning mode [1].

In Wendelstein 7-X (W7-X) experiments, collapse events were also observed in the plasma core [2]. One characteristic of W7-X is its low magnetic shear, which makes it very sensitive to profiles with localized toroidal current densities. If strongly localized toroidal current densities appear, in particular, in the case of co-current ECCD, the iota may easily achieve unity which is expected to be very sensitive to island formation or instabilities. The observed collapse events have similar characteristics to tokamak sawtooth crashes. The measured fluctuations are consistent with an $(m,n)=(1,1)$ resonance. Interesting questions arising are the magnetic topology of the crash and its nonlinear saturation state.

In this study, we use 3D nonlinear MHD-simulations to investigate these phenomena in W7-X. The nonlinear simulation is initialized by an equilibrium calculated with the 3D MHD equilibrium code, HINT, which does not assume nested flux surfaces [3]. In the nonlinear 3D equilibrium calculation, the impact of the localized toroidal current density on the iota profile is emphasized. For the 3D nonlinear MHD simulations, we use the MIPS code [4]. In the 3D nonlinear simulation, the emphasis is on the onset of the instability on the iota profile and the topological change of the magnetic field during the crash.

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