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Nonlinear MHD modeling of sawtooth-like crashes and ballooning modes in W7-X

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Sawtooth-like core electron temperature crashes have been observed in W7-X experiments with electron cyclotron current drive. We present nonlinear MHD simulations of this phenomenon using the newly developed stellarator modeling capability of the M3D-C1 code. The near-axis current drive gives rise to two $\iota = 1$ resonances in the equilibrium rotational transform profile so that two consecutive (1,1) internal kink modes are seen in the simulations. A small-amplitude crash at the inner resonance occurs first, which may correspond to the sawtooth precursors observed in the experiments. A bigger crash at the outer resonance then flattens the core temperature profile, which shows semi-quantitative agreements with experimental measurements on metrics such as the crash amplitude and the inversion radius of the temperature change. These results illustrate a likely mechanism of the current-drive-induced sawtooth-like crashes in W7-X and validate the stellarator modeling capability of M3D-C1. In addition, we present simulations of ballooning modes in high-beta W7-X plasmas, which show coherent nonlinear saturation and little mode coupling, only causing limited decrease in plasma energy. These results suggest that stellarator plasmas may be extra robust against pressure-driven instabilities.

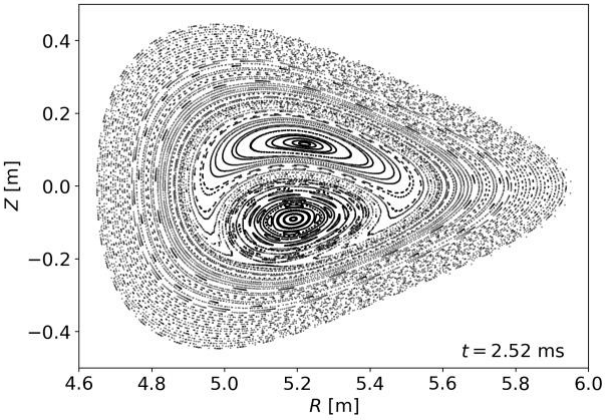

Figure 1. A snapshot of Poincaré plot in the M3DC1 simulation showing a (1,1) internal kink mode in the core causing the sawtooth-like temperature crash.

References:

[1] Yao Zhou, K. Aleynikova, and N. M. Ferraro. Nonlinear magnetohydrodynamic modeling of current-drive-induced sawtooth-like crashes in the W7-X stellarator. Physics of Plasmas, 30(3), 032503 (2023).
[2]Yao Zhou, N. M. Ferraro, S. C. Jardin, and H. R. Strauss, Approach to nonlinear magnetohydrodynamic simulations in stellarator geometry, Nuclear Fusion 61(8), 086015 (2021).