Magnetohydrodynamic Simulations of Sawtooth Crash Induced Electron and Impurity Transport in Tokamak Plasmas

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The transport of impurities in fusion plasmas has become a growing concern recently due to the use of Tungsten as divertor material in recent machines, in preparation for ITER. The radiation cooling induced by the presence of Tungsten will prevent ITER operation for a concentration as small as 0.02% [1]. The transport of Helium ash is also an issue, since accumulation of Helium in the core can dilute the D-T mixture and reduce performance. Sawteeth, which cause periodic redistributions of the core energy and particle content, can provide a way to expel the impurities of the core. However, contrary to the energy case, the modification of particle density profiles (electron and impurities) by the sawtooth crash is not well known, neither experimentally nor theoretically. In this study, we present non-linear 3D bifluid full MHD simulations of sawtooth crashes and their impact on electron and impurity density profiles, using the XTOR-2F code [2].

Regarding the electron density, it is remarkable that the post-crash profile is not flat after the crash, but displays a small amplitude crescent-shaped structure inside the q=1 surface. This structure was observed recently on the Tore Supra and JET tokamaks using fast-sweeping reflectometry technique. Using the simulations, the origin of the structure is found to be the fast perpendicular flows related to the kink instability giving rise to the sawtooth crash [3], rather than fast transport along reconnected field lines, the mechanisms responsible for the observed temperature flattening.

The presence of the crescent-shaped structure has a small impact on the total electron particle balance because of the small profile peaking in the core, however it raises concern about the impurity transport because impurity profiles can be much more peaked. Simulations with an extended version of the XTOR-2F code, which allows to simulate passive scalar impurities, reveal that even for peaked impurity profiles, the main effect of the sawtooth crash is to flatten the density profiles. A crescent-shaped structure is present, but its amplitude is too small to small to significantly modify the particle balance [4].

The general conclusion is that the efficiency of the sawtooth crash in flattening the core profiles is as efficient as initially assumed.

[1] T. Pütterich, et. al., *Nuclear Fusion* **50(2)**, 025012 (2010)
[2] H. Lütjens, et al., *Journal of Computational Physics* **229(21)**, 8130 (2010)
[3] T. Nicolas, et al., *Physics of Plasmas* **19(11)**, 112305 (2012)
[4] T. Nicolas, et al., *Physics of Plasmas* **21(1)**, 012507 (2014)