Sawtooth-like crashes at W7-X

M. Zanini, K. Aleynikova, B. Buttenschön, C. Brandt, H. Braune, K.J. Brunner, A. Dinklage, Y. Gao, M. Hirsch, U. Höfel, J. Knauer, H.P. Laqua, S. Marsen, N. Maruschchenko, A. Pavone, K. Rahbarnia, J. Schilling, T. Stange, E. Strumberger, H. Thomsen, Y. Turkin, R.C. Wolf, Q. Yu, A. Zocco and the W7-X Team

W7-X is an advanced optimised superconducting stellarator with low shear magnetic configurations designed to avoid major resonant surfaces within the confinement region [1]. Since W7-X is equipped with an island divertor that requires the rotational transform (ɨ) of the magnetic field to be constant at the plasma edge, the magnetic configurations are adjusted so that bootstrap current vanishes, or, alternatively, the bootstrap current is balanced by strong Electron Cyclotron Current Drive (ECCD). ECCD experiments have been conducted in order to assess the capabilities of ECCD for strikeline control, which is crucial for future operations, in order not to damage the components of the machine. However, during ECCD experiments, periodic sawtooth-like crashes were observed [2]. These sawtooth-like crashes are characterised by a fast drop of the central electron temperature, as a result of the hot core expulsion. There are also examples of discharges where related events lead to complete termination of the entire plasma [3].

A current diffusion model with Kadomtsev-like relaxations was developed to calculate the current and the rotational transform profiles, showing a good agreement with selected experiments [4]. The rotational transform is modified in such a way that low order rational values are crossed and several types of crashes are identified. Additionally, ideal and non-ideal (resistive and kinetic) simulations were conducted using different stability codes. It was shown that the plasma is marginally stable to ideal modes, but can be destabilised by non-ideal effects. In particular, a (m,n) = (4,4) and (m,n) = (1,1) are found to be the dominant modes [5-7].

The analysis of experimental data shows that several different types of crashes (with different affected volumes and amplitudes) can be recognised. The size of the crashes is not constant and a dependence on the toroidal current was found. The joint analysis of Electron Cyclotron Emission (ECE) and soft x-ray tomography shows that larger temperature crashes are preceded by a fast displacement of the plasma core (consistent with a (m,n) = (1,1) mode) [2] which is in agreement with the main results of the current evolution modelling and the performed simulations. Experimental data also indicate the presence of a magnetic island preceding the temperature crash, confirming the non-ideal nature of the instability. Finally, the plasma termination events are found to be related to very large crashes, although no damages to the machine have been detected.

[1] R.C. Wolf et al 2017 Nucl. Fusion 57 102020
[2] M. Zanini et al. 2020 Nucl. Fusion 60 106021
[3] M. Zanini et al 2021 Nucl. Fusion 61 116053
[4]K. Aleynikova et al 2021 Nucl. Fusion 61 126040
[5] Q. Yu et al 2020 Nucl. Fusion 60 076024
[6]E. Strumberger and S Günter 2020 Nucl. Fusion 60
[7]A. Zocco et al 2021 Nucl. Fusion 61 086001