Destabilization of fast particle stabilized sawteeth in ASDEX Upgrade with ECCD

V. Igochine[1], I. Chapman[2], V. Bobkov[1], M. Maraschek[1], D. Moseev[3], M. Reich[1], J. Stober[1], ASDEX Upgrade team[1]

[1]*MPI für Plasmaphysik, Euratom-Association, D-85748 Garching, Germany*

[2]*Culham Centre for Fusion Energy (CCFE), Culham Science Centre, Abingdon, Oxfordshire OX14 3DB, UK*

[3]*EURATOM-Risø DTU, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, DK-4000 Roskilde, Denmark*

Introduction

In magnetically confined fusion plasmas, a variety of magnetohydrodynamic (MHD) instabilities can occur, driven by gradients of kinetic pressure or current density. The sawtooth oscillation is one of the fundamental instabilities in tokamaks. It is associated with abrupt changes in central plasma confinement due to growth of an (m,n)=(1,1) mode [1]. Whilst the plasma usually survives the drops in core temperature and density due to this instability, the triggering of other, more dangerous instabilities is the main concern. It is often observed that large sawteeth trigger the neoclassical tearing mode (NTM) well below the threshold for this instability [2]. In future reactors like ITER, the fusion born α-particles will stabilize the (1,1) mode and lead to larger sawteeth which are more probable to trigger NTMs. Thus, avoidance of large sawteeth is of prime importance for a robust scenario in ITER. The second possible problem for ITER could come from redistribution of the fast particles during the crash which is expected to be larger for larger sawteeth.

The main aim of this work is reproducing of ITER relevant situation. The fast α-particles are mocking up with central ICRH heating in ASDEX Upgrade. This heating produces a population of the fast ions in the plasma core which stabilizes the (1,1) mode and increases the sawteeth period. The destabilization of the sawteeth is achieved by local changes of the current profile with electron cyclotron current drive (ECCD). These changes are done by changing the ECRH mirror angle. (Previous experiments in ASDEX Upgrade used variation of toroidal magnetic field to change ECCD deposition position, which is not possible in ITER [3,4].)

Sawteeth destabilization experiments

The reported experiments employ the standard operation parameters of ASDEX Upgrade tokamak: $I_{plasma} = 1MA$, $n_e = 8 \cdot 10^{19} m^{-3}$, $B_{toroidal} = 2.5T$, $q_{95} = 4.7$. Sawteeth inversion radius is located at $\rho_{pol} = 0.36 - 0.38$. The heating scheme includes high ICRH power $(P_{ICRH} = 4.25MW)$ and two NBI sources $(P_{NI} = 2.5MW)$. The 140GHz ECRH system is used to heat plasma in the core which avoids impurity accumulation and provide stable discharge conditions.

As was mentioned before, central ICRH heating produces a population of the fast ions in the plasma core which stabilize the (1,1) mode and increase the sawteeth period. The destabilization of the sawteeth is achieved by local changes of the current profile with electron cyclotron current drive (ECCD). The radial position of the ECCD is swept poloidally during the discharge, corresponding to a sweep of the resonant location from inside to the outside of q=1 surface. Changes of the sawteeth period depending on time and on the deposition position are shown for co-current drive case in figure 1. Result of the experiments shows that co-current ECCD inside q=1 surface destabilizes sawteeth and reduces sawteeth period by about 40%. Consequently, the outside deposition stabilizes sawteeth. The deposition profiles for different time points are shown in figures 2 and 3. The width of the deposition profile is relatively broad in comparison with previous experiments [3]. On the one hand, this is unfavourable for sawtooth control but on the other hand, a similar situation is expected in ITER. This broad deposition profile is a result of the off-axis injection geometry and has pure geometrical origin. The advantage of the present system is an almost constant deposition profile (see figure 2). Our results confirm recent findings from ToreSupra that moderate ECCD is able to destabilize fast particle stabilized sawteeth [5].

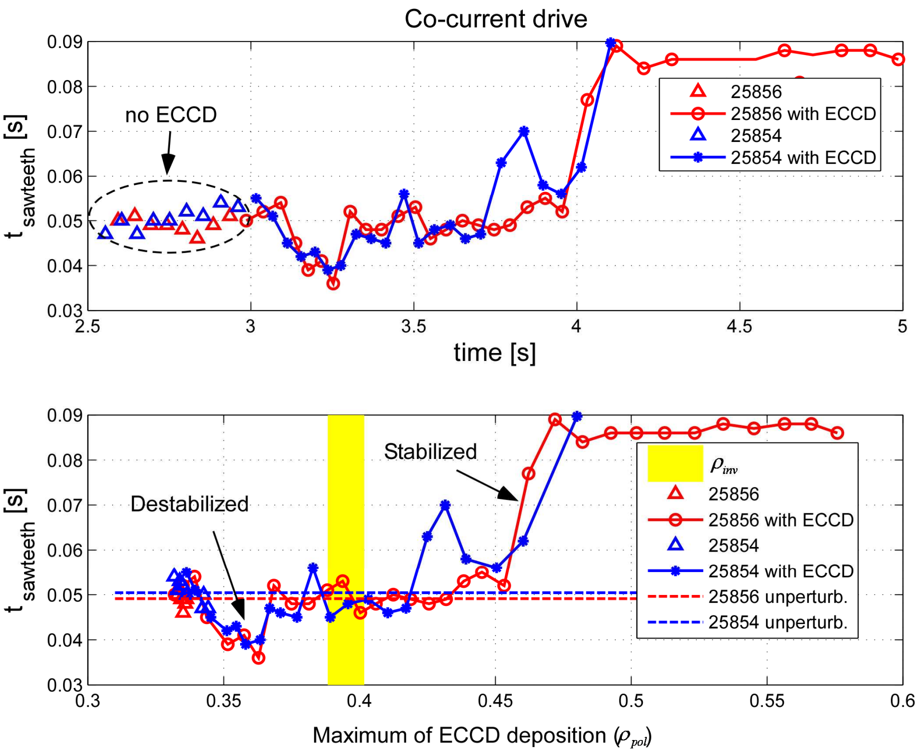
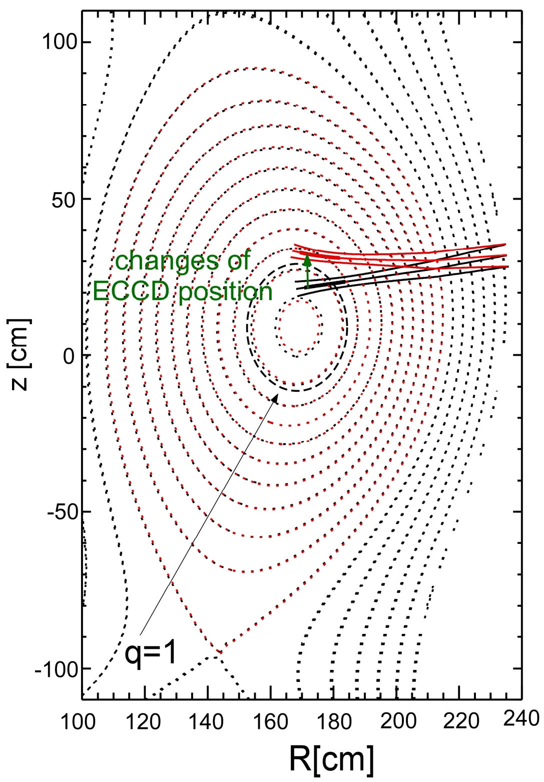


Figure 1. Changes of the sawteeth period depending on time (first figure) and maximum of ECCD deposition position (second figure) are shown for co-current drive case. Co-current ECCD is applied from 3 second. The current drive position changes from inside of the q=1 surface to the outside as shown in second figure. Sawtooth inversion radius is marked.



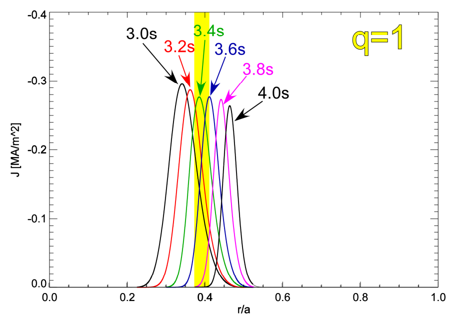


Figure 2. Co-ECCD deposition profiles for different time points for discharge 25856. Position of q=1 surface is marked.

Figure 3. Changes of the co-current ECCD locations during the scan from inside to the outside of q=1 surface

A single attempt to explore the effect of counter-current drive was inconclusive because of high scatter of the sawtooth period values already in ECCD free phase in this discharge (see figure 4).

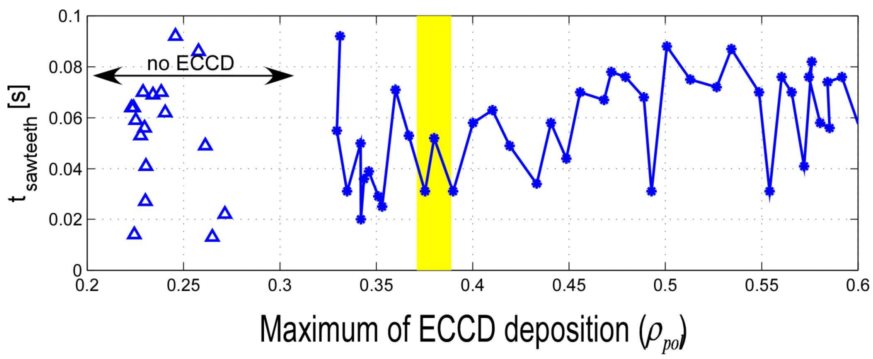


Figure 4. Results of counter-current drive experiment are shown. The sawtooth period is not stable (both with and without ECCD). Inversion radius is marked by yellow line.

Conclusion

The first experiments in ASDEX Upgrade show that ECCD is able to destabilize the fast particle stabilized sawteeth. It is clear that further experiments are necessary to identify the efficiency of the both co- and counter- ECCD and effect of pure ECRH heating. The amount of stabilizing influence of the fast particles on the sawteeth is the subject of current calculations. In such calculation the effect of ICRH heated neutral beam ions will be taken into account.

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